Poly-carbonmonofluoride Lithium Batteries (CF)n/Li

Cylindrical Type Lithium Batteries

1. Preface

National poly-carbonmonofluoride lithium batteries, hereafter called (CF)n/Li batteries, were developed through National world leading technology, and are the result of diligent research into long life and high reliability. They have been mass-produced since 1971, and lead the world in reliability and safety.

Lithium has the highest negative potential of all metals, making it the most ideal material for battery anode. The world's battery researchers, in quest of high voltage and high capacity battery characteristics, have devoted themselves to developing cathode materials to complement the lithium anode. As a result of thorough research into the energy density and safety of possible cathode for lithium batteries, National succeeded in developing poly-carbonmonofluoride (CF)n, which has proven to be the ideal material for battery cathode.

Since the development of (CF)n/Li in 1971, National has expanded the variety of sizes, and continues to improve the characteristics and quality in response to market needs. As a result, utilizing its unique automated production and management technology, National has perfected commercial production of lithium batteries.

At the same time, new fields have continued to develop in the rapidly growing electronics industry, varying from applications for IC memory back-up (requiring a small discharge current), to heavy current drain applications. For example, the BR-2/3A battery, used in disc cameras, can supply an instantaneous current of several amperes. Once installed in the camera as the prime power source, a life of 5 years is guaranteed.

The BR-C, BR-A, BR-1/2A, and BR-2/3AA batteries are based on the same development and mass-production concepts.

Because the reliability of batteries cannot be confirmed in short-term accelerated tests, National remains dedicated to the principle of continuous actual testing of product. As a result the data offered by National for our lithium batteries are backed by more than 10 years of development and testing.

The National (CF)n/Li batteries have been patented in major countries around the world, including the United States, England, West Germany, and the USSR, and they are manufactured under our license by some of the world's leading battery manufacturers.

2. General Information

National (CF)n/Li batteries possess unique features beyond those common to other lithium systems. Above all, (CF)n/Li batteries are totally safe system. It is chemcially stable and non-toxic. National (CF)n/Li batteries have UL component recognition.

Important features and uses of (CF)n/Li batteries are described in the following section:

2.1 General Features

The poly-carbonmonofluoride battery features:

- **High voltage**
- **High energy density**
- **Long sheft life**
- **Stable operation**
- **Flat discharge voltage & stable internal impedance**
- **High rate discharge**
- **Wide operating temperatures**
- **Strong leakage resistance**
- **Excellent durability**
- **Excellent safety**

These features are described in detail, in section 2.5.

2.2 Applications

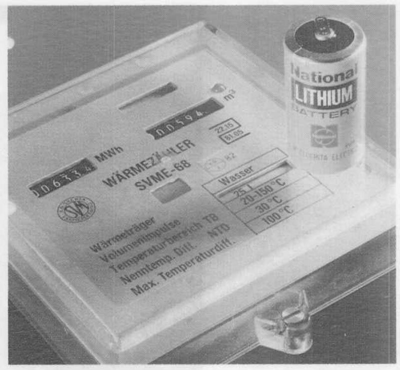
Applications taking advantage of these features are increasing in many fields.

Cameras:

Used as the main batteries for disc cameras and 35mm automatic cameras with built-in flash. Depending on the frequency of use, the same batteries can be used for 5 or even 10 years. The batteries will never completely discharge when not used. This application takes advantage of such features as high energy in a compact size, practically no capacity deterioration even when stored, high rate discharge capability, and low temperature use.

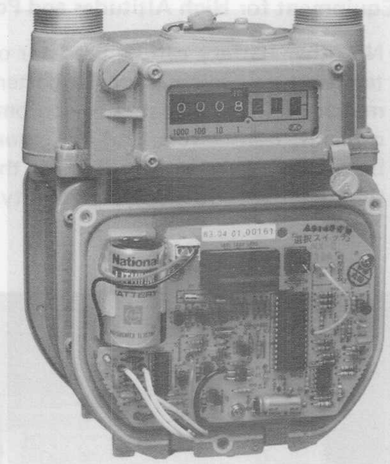
Electronic Water Meter:

There are plans to convert mechanical meters to electronic meters and to use them for central metering through the telephone lines in the future. This is a new field for batteries. A minimum requirement for water meters now used in Japan is that they operate without maintenance for 8 years. Therefore, including the time the meters are stored in the warehouse, the batteries must be able to operate continuously for a minimum of 10 years. They must be able to operate under wide temperature ranges since the meters will be installed outdoors. Only (CF)n/Li batteries have been able to meet these conditions.



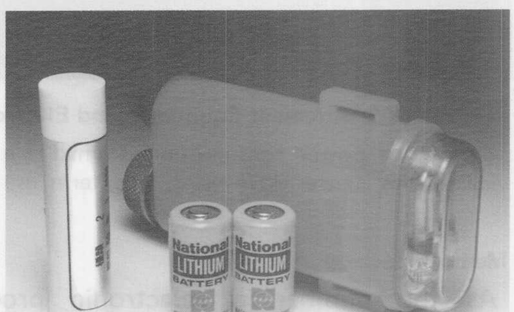
Hot Water Meter:

Commonly used in Europe. Batteries are used as the power source for systems which check the quantity and temperature of centrally supplied hot water and calculate the calories (BTU's). It is desirable to use the same set of batteries for as long a period as possible. The meters use pulsed current ranging from several mA to several 100mA. The batteries must also withstand the high temperatures of the hot water. (CF)n/Li batteries are well suited for this application.



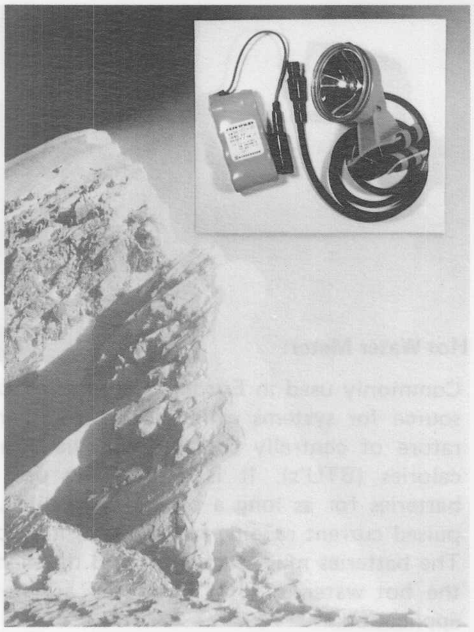
Gas Safety Emergency Cutoff System:

In this system, the gas valve is closed when an abnormal flow of gas is detected. The batteries must be able to supply several 100mA of current to close the gas valve, as well as supply a small current (including pulsed current) for 10 years or more. Again, (CF)n/Li batteries are perfectly suited for this application.



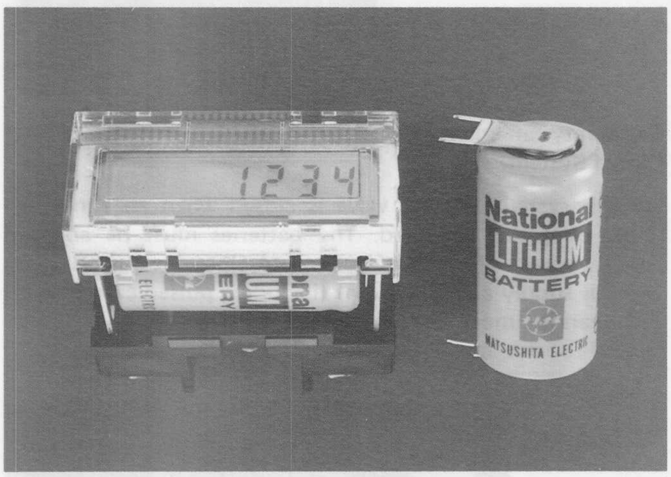
Emergency Signal Light:

This is a light which is normally off, but flashes during an emergency. Shelf life and reliability are the first requirements. Installation may be in rugged environments, thus the batteries must be able to withstand wide temperature ranges. These are frequently used to find/rescue downed flyers in remote locations.



Equipment for High Altitudes and Polar Regions:

No other battery can be used for operation in extreme low temperature regions. Special battery packs are designed to match the characteristics of equipment such as lamps, 8mm cameras, transceivers, and navigators. High energy (CF)n/Li batteries are perfectly suited for these products because of their light weight and dependability.



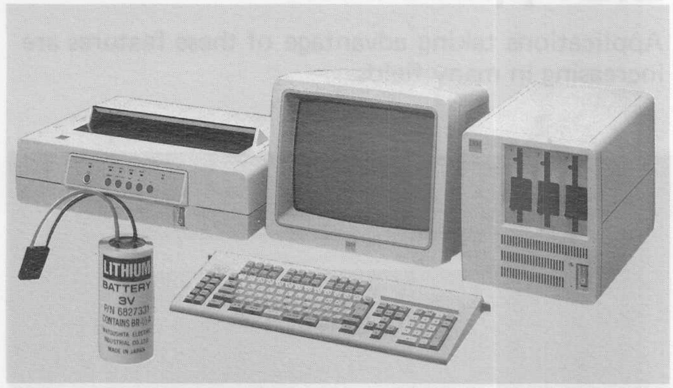
Electronic Measurement Equipment and Electronic Counter:

Since their power consumption is small due to the use of electronics, batteries insuring long term use are required.

Memory Back-up

As the number of electronic products with memory functions continues to increase, more and more batteries are needed for back-up when the main power is turned off. Only lithium batteries can fit the need for compactness, high capacity, and long life. They are also maintenance free even after 10 years and can be directly soldered onto PC boards.

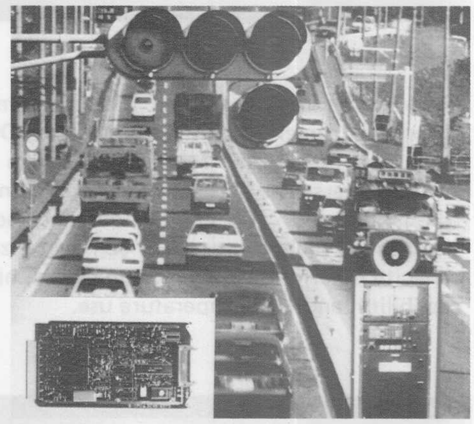
Major Applications



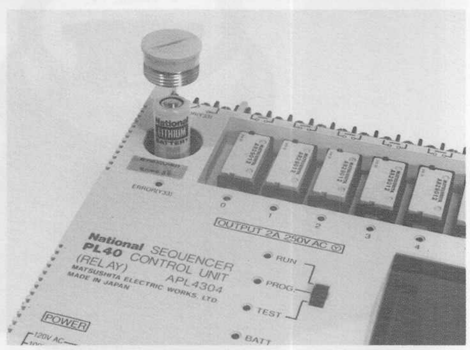
MICROCOMPUTER

Office Equipment:

Copiers, electronic cash registers (ECR), point of sale (POS) terminals, microcomputers, handheld computers, facsimiles, electronic typewriters, CRT displays, electronic stamping machines (post office systems), etc.



TRAFFIC SIGNAL



SEQUENCER

Industrial Equipment:

Sequencers, traffic signal, welders, robots, and temperature adjustment.

Communication Equipment:

Electronic telephones, switchboards, and car telephones.

Home Electronics:

Tuner memories of TVs and Video recorders, and electronic organs.

Automotive Equipment:

Electrical equipment, meters, control circuits, and car telephones.

2.3 Electrochemical Processes

Anodes and cathodes with high voltage (V) and high capacity (Ah) must be combined to produce high energy density batteries.

Lithium has the highest negative potential of all metals, and thus is the most desirable material for an anode.

A great variety of battery compositions are possible by combining lithium with various cathode materials.

Energy densities of these batteries can be calculated by respective reaction equations. Table 1 shows theoretical energy densities of lithium batteries compared with those of conventional batteries. Even if high voltage batteries are desired, batteries using aqueous electrolyte have a maximum voltage of 2V (lead acid batteries) due to water decomposition voltage. Lithium reacts chemically with water so that aqueous electrolyte cannot be used in lithium batteries. Lithium batteries have achieved high energy density by using a non-aqueous organic solvent for electrolyte.

Table 1. Theoretical energy densities of main lithium batteries compared with those of conventional batteries.

Reaction	E°	(Wh/kg)	
$nLi+(CF)n \rightarrow nLiF+nC$	3.2*	2,260	Poly-carbonmonofluoride Lithium Battery
$8Li+3SOCl_2 \rightarrow 6LiCl+Li_2SO_3+2S$	3.61*	1,877	Thionyl Chloride Lithium Battery
$2Li+CuF_2 \rightarrow 2LiF+Cu$	3.54	1,645	———
$2Li+NiF_2 \rightarrow 2LiF+Ni$	2.83	1,370	———
$2Li+2SO_2 \rightarrow Li_2S_2O_4$	2.95*	1,114	Sulfur Dioxide Lithium Battery
$2Li+2MnO_2 \rightarrow Li_2O+Mn_2O_3$	2.69	768	Manganese Dioxide Lithium Battery
$2Li+Ag_2CrO_4 \rightarrow Li_2CrO_4+2Ag$	3.35*	520	Silver Chromate Lithium Battery
Conventional batteries			
$Zn+2MnO_2 \rightarrow Zn^{2+}+2MnOOH$	1.7	234	Carbon Zinc Battery
$Zn+HgO \rightarrow Zn(OH)_4^{2-}+Hg$	1.4	266	Mercury Battery
$Zn+Ag_2O \rightarrow ZnO+2Ag$	1.6	287	Silver Oxide Battery

2.4 Construction

Cathode

Basic characteristics of lithium batteries, such as voltage and discharge capacity, are determined according to the type of cathode material used.

Fluorocarbon is an intercalation compound produced through direct reaction of carbon powder and fluorine gas, and is expressed in (CFx)n.

Fluorocarbon, formed in optimal fluorination conditions, i.e., X = 1, is white powdered poly-carbonmonofluoride. When fluorine atoms enter the inter layer space of graphite, the interlayer distance is increased in the C-axis direction, thus forming zigzag structure. A similar structure is formed by fluorinating coke or active carbon other than graphite. Poly-carbonmonofluoride is chemically stable and does not thermally decompose up to 400°C. As an active battery material, it does not react with the organic electrolyte or dissolve. Poly-carbonmonofluoride is thus highly safe and electrochemically active, and allows the discharge reaction to proceed effectively, and safely.

Basic studies on the discharge reaction mechanism have been conducted at home and overseas ever since poly-carbonmonofluoride lithium batteries were invented in Japan. The open circuit voltage of the poly-carbonmonofluoride electrode in organic electrolyte is 3.0 ~ 3.5V. As for the discharge reaction, it has been recognized that the peak of poly-carbonmonofluoride as seen in X-ray diffraction, disappears, shortening interlayer distance and producing amorphous carbons as discharge proceeds and that crystalline lithium fluoride (LiF) is simultaneously formed.

General discharge reaction can be expressed by the following equation (1):

$$nLi + (CF)n \longrightarrow nLiF + nC \quad \ldots\ldots\ldots\ldots (1)$$

Since poly-carbonmonofluoride is highly resistant material, in actual batteries, the cathode is pressure-formed by mixing in a conductive material, such as acetylene black, and adding a binder, such as fluoride resin.

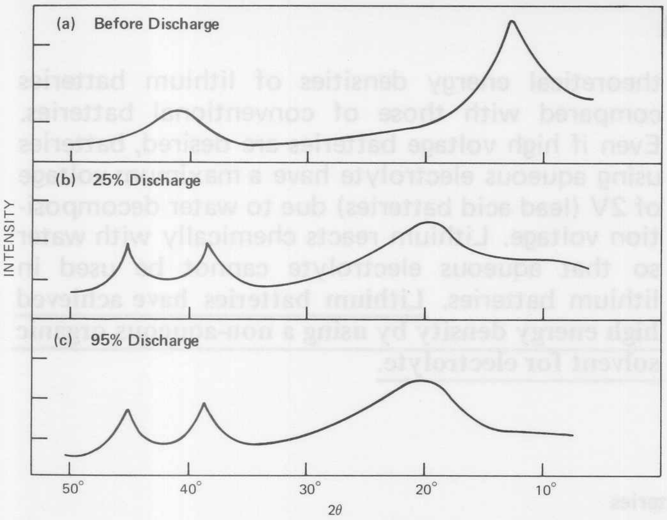


Fig. 1 X-ray diffraction patterns of the (CF)n electrode during discharge.

Table 2 Physical properties of some organic solvents for lithium batteries.

Solvent	Structure	Boiling point (1 atm, ℃)	Melting point (℃)	Density (25℃, g/ml)	Dielectric constant (25℃)	Viscosity (25℃ cp)
Dimetyl-formamide (DMF)	$(CH_3)_2N-C(=O)-H$	153	−61	0.94	36.7	0.802
γ-Butyrolactone (γ-BL)	CH_2-CH_2, O, CH_2, $C=O$ (ring)	204	−43.5	1.1254	39.1	1.751
Tetrahydrofuran (THF)	CH_2-CH_2, CH_2, CH_2, O (ring)	66	−108.5		6.2	0.48
Acetonitril	$CH_3-C\equiv N$	81.7	−45.8	0.78	38	0.345
Water	H_2O	100	0	0.99	78	0.895

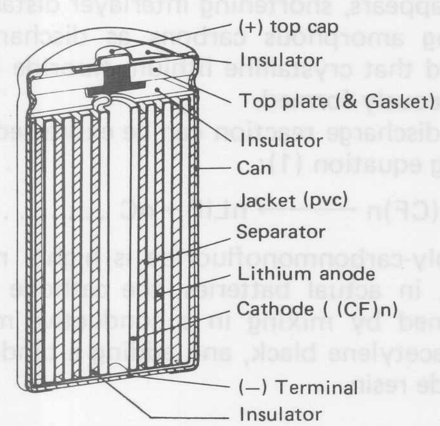


Fig. 2 Cross sectional view of cylindrical type Lithium Battery

Anode

The active anode material, lithium, is the lightest metal, with an electric capacity of 3.86Ah/g. The electrode reaction is expressed by $Li \rightarrow Li^+ + e$ where the lithium is dissolved during discharge. Lithium is also the most negative metal with a standard electromotive force of $Eo = -3.045V$. Therefore, lithium is the most suitable anode for production of high voltage and light weight batteries.

The lithium anode is composed of flat lithium sheet pressed onto a metal collector, such as nickel or stainless steel.

Electrolyte

An alkalimetal salt is dissolved in a non-aqueous organic solvent to produce an electrolyte with ionic conduction. An aprotic organic solvent with a high dielectric constant, low viscosity, and a high boiling point is used for the electrolyte. (Table 2)

Separator

The separator is an insulative thin porous assembly with high ion permeability and adequate mechanical strength. Polyolefin non-woven cloth, such as polypropylene, is used according to application.

Structure

Cylindrical type lithium batteries have a spiral structure, as shown in Fig. 2, the cathode and anode sandwich the separator, and are formed spirally and encased in a Ni-plated steel can.

2.5 General Characteristics

2.5.1 Voltage

The nominal voltage is 3V, approximately double that of carbon zinc batteries, mercury batteries, and silver oxide batteries. As a result, circuits previously requiring the use of 2 or 3 batteries connected in series can now be driven with a single battery. For example, Fig. 3 shows the relationship between the operating voltage of a typical CMOS IC and various battery voltages. It is clear that a single (CF)n/Li battery is sufficient for operation.

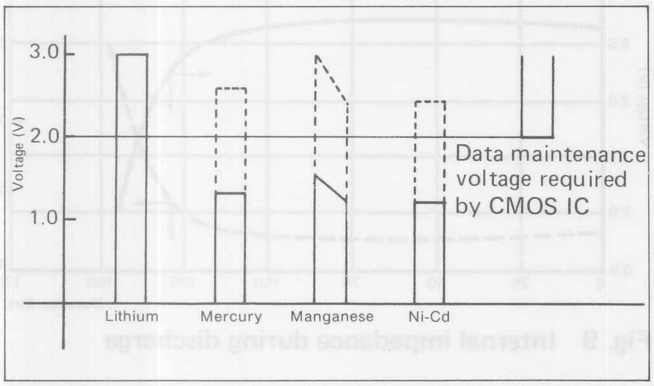


Fig. 3 CMOS IC Operating Voltage and Various Battery Voltage

2.5.2 Energy Density

The theoretical energy density of conventional batteries and various type of lithium batteries are shown in Table 1. (Section 2.3)
The discharge curves of (CF)n/Li batteries and carbon-zinc batteries are compared in Fig. 4 and Fig. 5. They show that at 20°C (room temperature), (CF)n/Li batteries have an energy density approximately 5 times that of carbon zinc batteries; and at −10°C they have approximately 10 times the energy density.

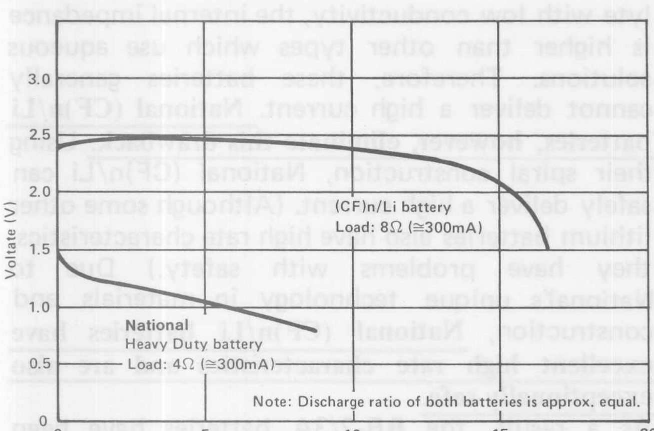


Fig.4 Comparison of (CF)n/Li and Carbon zinc battery (C size)

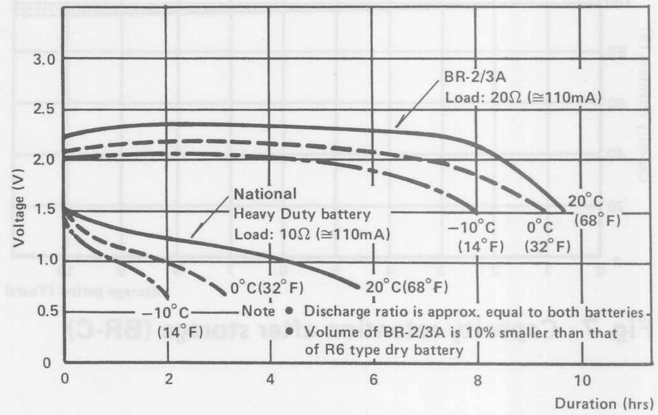


Fig. 5 Comparison of BR-2/3A lithium battery and R6 carbon zinc battery

2.5.3 Shelf Life

(CF)n, the active material of the cathode, is, chemically, and thermally extremely stable. Even if the battery is stored for long periods of time, there is hardly any deterioration of the active material.
The electrical characteristics of the BR-C battery after more than 10 years of storage are shown in Fig. 6 and Fig. 7. They show that the annual deterioration rate is only about 0.5%. The only difference between the initial characteristics and those after 10 years storage is a very slight lowering of the operating voltage. Thus, there is practically no need to consider the deterioration rate when designing battery-powered equipment.
This feature makes the (CF)n/Li batteries ideally suited for use in emergency equipment which must be ready for operation at any time. When used as the prime power source in equipment or cameras, they can be called upon for use at any time up to 10 years.

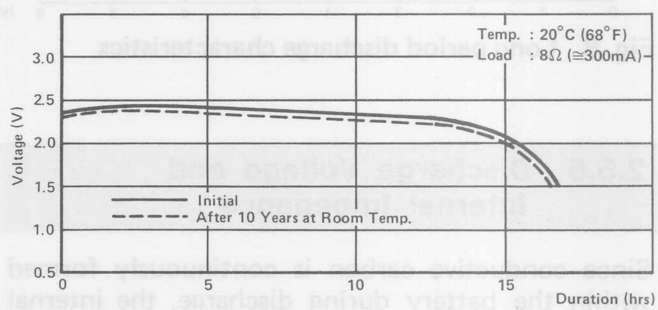


Fig. 6 Storage characteristics (BR-C)

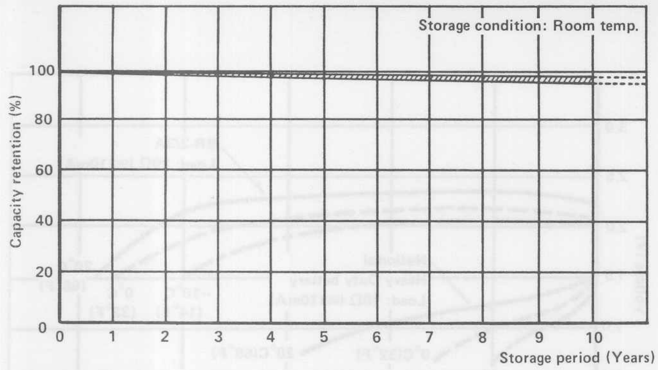


Fig. 7 Capacity retention after storage (BR-C)

2.5.4 Stable Operation

With the development of semiconductor technology such as CMOS, there are many new applications where a small current flows continuously over an extended period of time. Since (CF)n/Li batteries have almost no self-discharge, as described in the section on shelf life, they are ideally suited for these applications. The actual discharge characteristics of BR-2/3A batteries at approximately 20μA over a period of 7 years are shown in Fig. 8. Other applications include electronic water meters which require continuous operation for up to 10 years without replacement, and dependable back-up for IC memories.

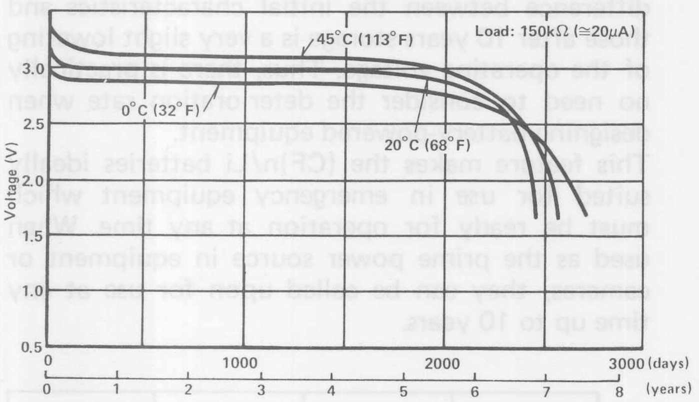


Fig. 8 Long period discharge characteristics

2.5.5 Discharge Voltage and Internal Impedance

Since conductive carbon is continuously formed within the battery during discharge, the internal impedance does not increase until the end of the discharge. As a result, the battery delivers a uniform operating voltage. This flat voltage is desirable in various types of electronic equipment. Though the battery normally is discharged at a low rate in most applications, the low and stable internal impedance allows the battery to deliver a large pulsed current when required. For example, the BR-C battery is used in gas safety emergency cutoff systems (such as for city gas) where it discharges at a low rate for more than 8 years. Yet it can supply a current of 100 ~ 500mA to operate the emergency gas cutoff valve if an abnormal flow of gas is detected.
The discharge curve for the BR-2/3A battery and the change in internal impedance are shown in Fig. 9.

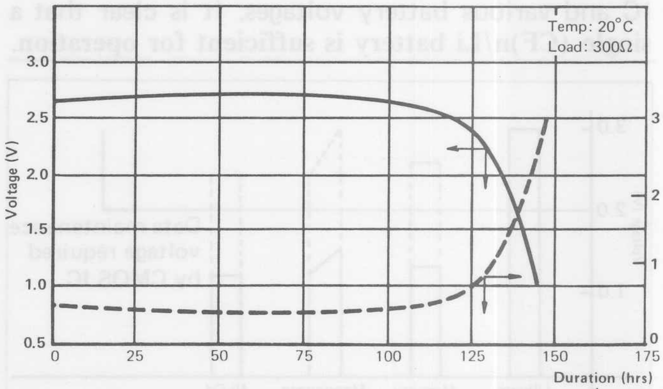


Fig. 9 Internal impedance during discharge

(CF)n/Li batteries do not have any noticeable voltage rise delay at the start of discharge.

Some lithium batteries, with a liquid active material for the anode, have an extreme voltage drop at initial discharge (such as after high temperature storage) since an inactive film covers the lithium surface.
The (CF)n/Li batteries use a solid active material for the anode which is separated from the lithium by the separator. Therefore with (CF)n/Li, this type of phenomenon does not exist.

2.5.6 High Rate Discharge

Since most lithium batteries use an organic electrolyte with low conductivity, the internal impedance is higher than other types which use aqueous solutions. Therefore, these batteries generally cannot deliver a high current. National (CF)n/Li batteries, however, eliminate this drawback. Using their spiral construction, National (CF)n/Li can safely deliver a high current. (Although some other lithium batteries also have high rate characteristics, they have problems with safety.) Due to National's unique technology in materials and construction, National (CF)n/Li batteries have excellent high rate characteristics and are also exceptionally safe.
As a result, the BR-2/3A batteries have been chosen by major manufacturers as the power source in cameras, a typical consumer product requiring instantaneous currents as high as several

amperes. The 1A pulse discharge characteristics of the BR-2/3A battery are shown in Fig. 10.

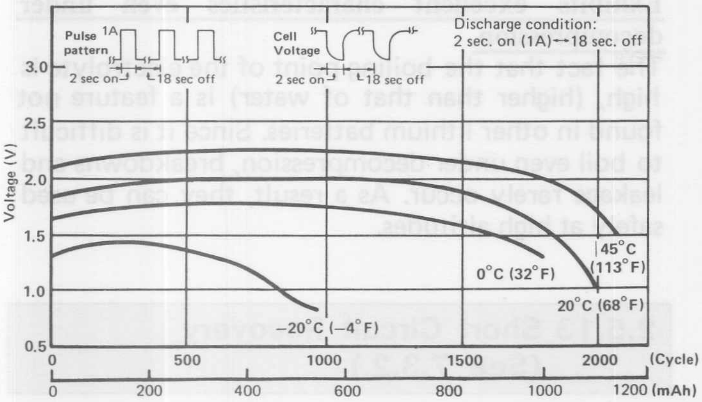


Fig. 10 Pulse discharge characteristics

2.5.7 Temperature Charcteristics

The (CF)n/Li batteries use an organic solvent for the electrolyte. The freezing point of the organic solvent, as shown in Table 2 (Section 2.4), is extremely low (−43.5°C). This means that the (CF)n/Li batteries can be used at temperatures as low as −40°C.

Further, since the boiling point of the organic solvent is high and the (CF)n cathode is stable even at high temperatures, there is practically no self-discharge. Thus, the battery can be used at temperatures at high as 85°C.

With their excellent low temperature ability, the batteries have been used in communications equipment and lamps at the North and South Poles and on Mt. Everest.

Utilizing their high temperature capability, they are used in direct sunlight operating backups for traffic signal and water meters, and have proven totally dependable for computer memory backup.

The discharge curves for the BR-2/3A battery in a wide range of temperatures are shown in Fig. 11. Fig. 12 shows the relationship of load and voltage versus temperature. (Note that the operating voltage changes according to the temperature.)

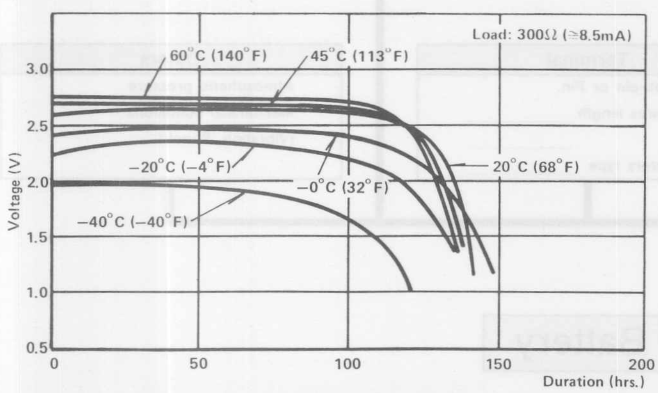


Fig. 11 Temperature characteristics

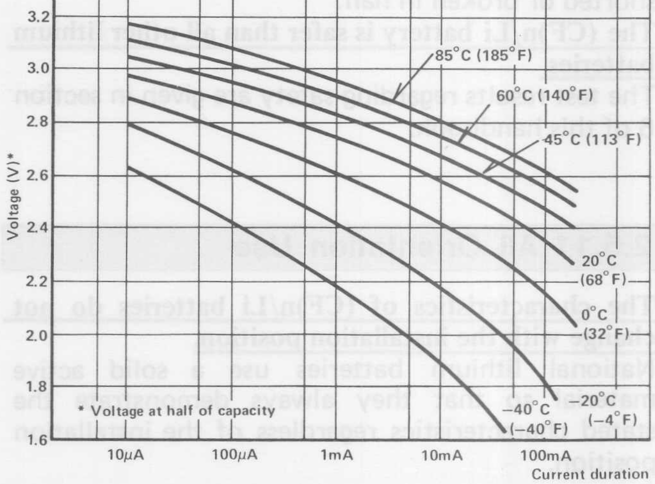


Fig. 12 Operating voltage vs. Current duration

2.5.8 Leakage Resistance

National uses an organic electrolyte with extremely low creepage. As a result, the leakage resistance is unsurpassed, especially when compared to other batteries using alkaline electrolytes. The (CF)n/Li batteries can be used safely in many types of equipment for long term use, without fear of leakage.

2.5.9 Durability

The (CF)n/Li batteries have been subjected to various extreme environmental tests such as thermal shock, temperature cycle, decompression, vibration, mechanical shock, and drop tests, to confirm their safety and reliability. The test results are given in section 6 of this handbook.

2.5.10 Safety

As mentioned in 2.5.3 on shelf life, the cathode active material of the (CF)n/Li batteries are extremely stable. National (CF)n/Li batteries are extremely safe, and do not use corrosive or toxic active materials or electrolyte.

Note: $SOCl_2$ uses corrosive and toxic active liquid materials. SO_2 uses active gaseous materials. Many of these other batteries use electrolytes with low flash points and have high deterioration during storage.

National batteries were designed to withstand use under severe conditions such as extreme temperatures, high currents, and even improper handling. For example, the batteries are constructed so that

they will not break down or ignite even when shorted or broken in half.
The (CF)n/Li battery is safer than all other lithium batteries.
The test results regarding safety are given in section 6 of this handbook.

2.5.11 All Orientation Use

The characteristics of (CF)n/Li batteries do not change with the installation position.
National lithium batteries use a solid active material so that they always demonstrate the stated characteristics regardless of the installation position.

2.5.12 High Altitude Use

Exhibits excellent characteristics even under decompression.
The fact that the boiling point of the electrolyte is high, (higher than that of water) is a feature not found in other lithium batteries. Since it is difficult to boil even under decompression, breakdowns and leakage rarely occur. As a result, they can be used safely at high altitudes.

2.5.13 Short Circuit Recovery (See 7.3.2.)

The batteries can be wave soldered. For details see section 7.3.2.

3. Battery Application & Selection Use

3.1 Application Guide

Points that must be considered when selecting a battery are shown in Fig. 1. This chart may also be used to indicate your particular operating conditions when ordering a custom design battery.

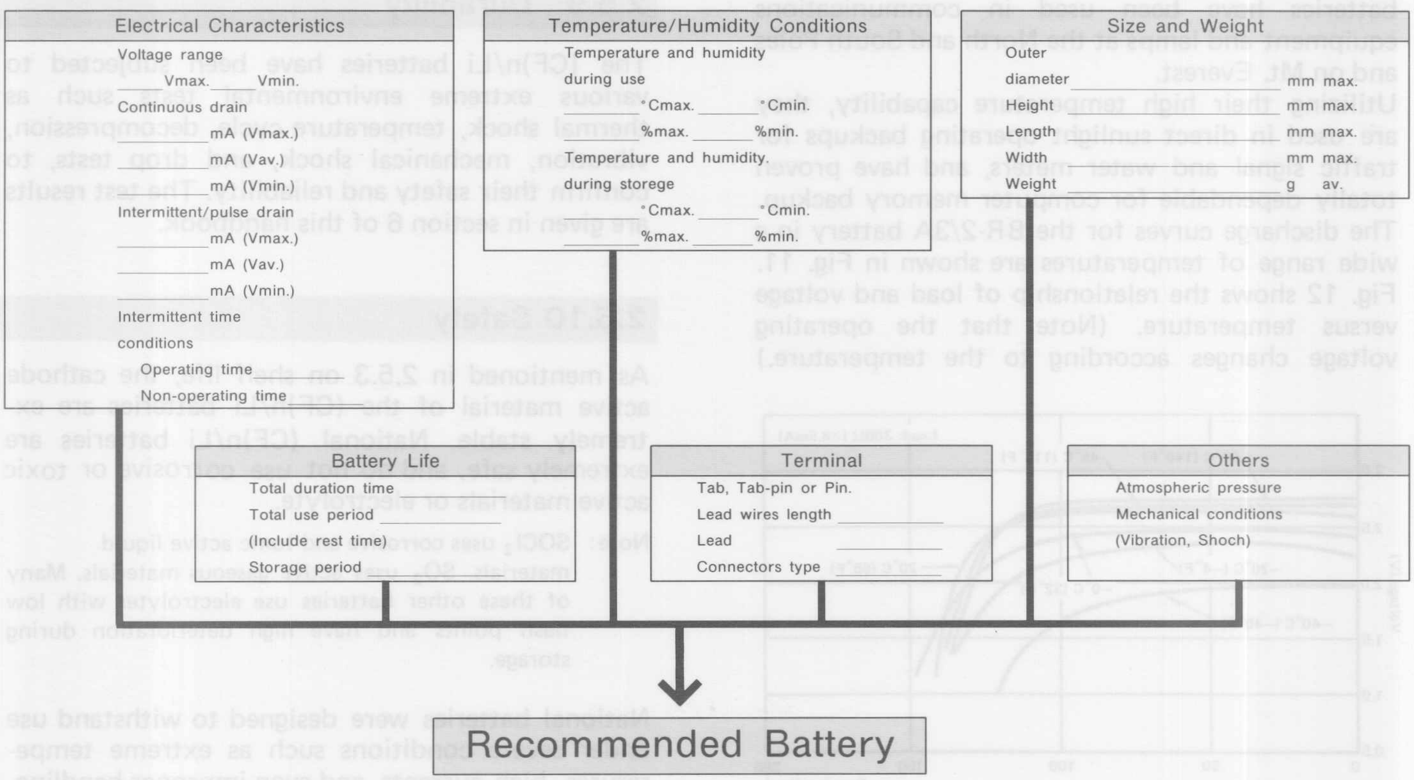


Fig. 1 Application Guide

3.2 Battery Selector Guide

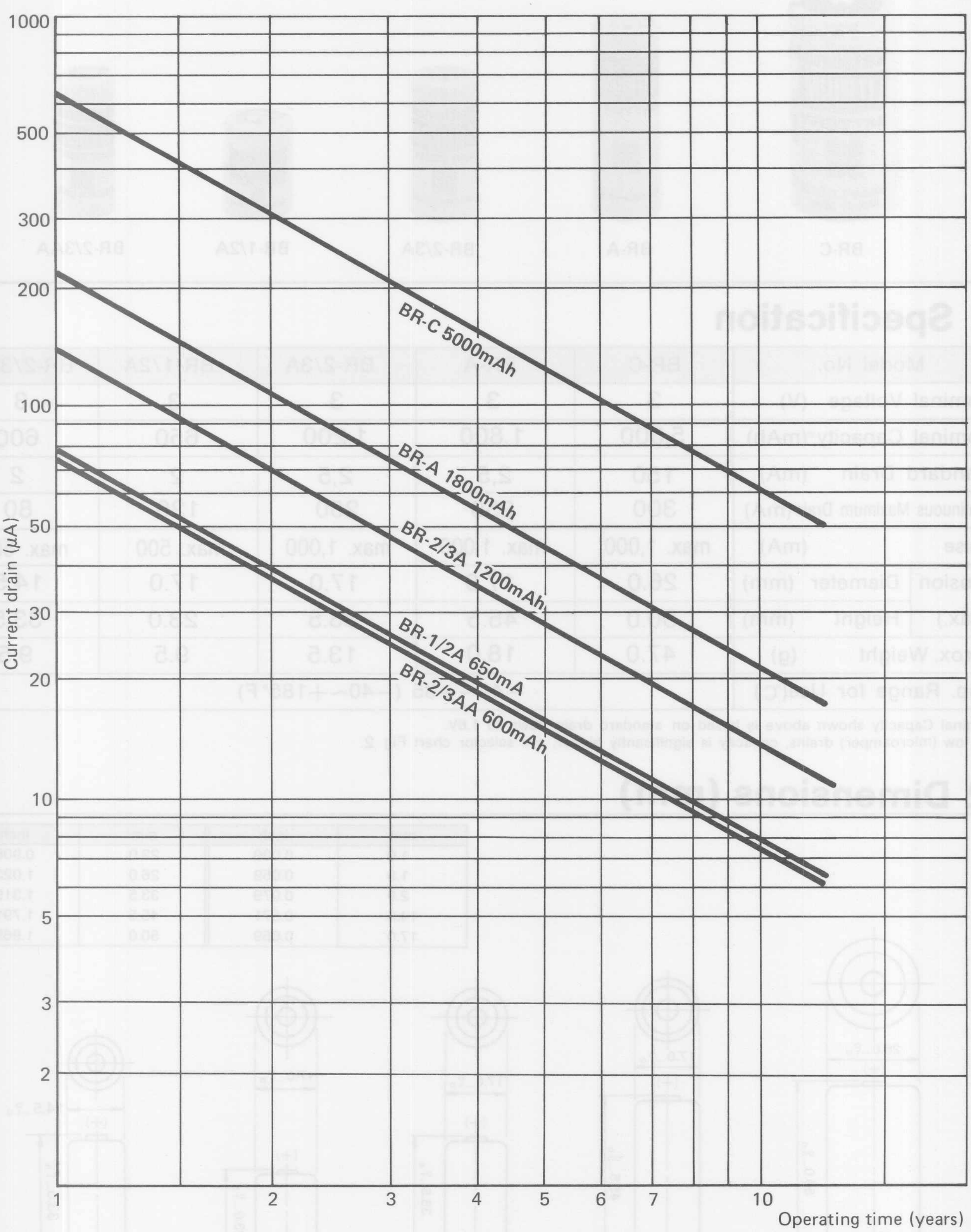


Fig. 2 Selector Chart

4. Specifications

BR-C BR-A BR-2/3A BR-1/2A BR-2/3AA

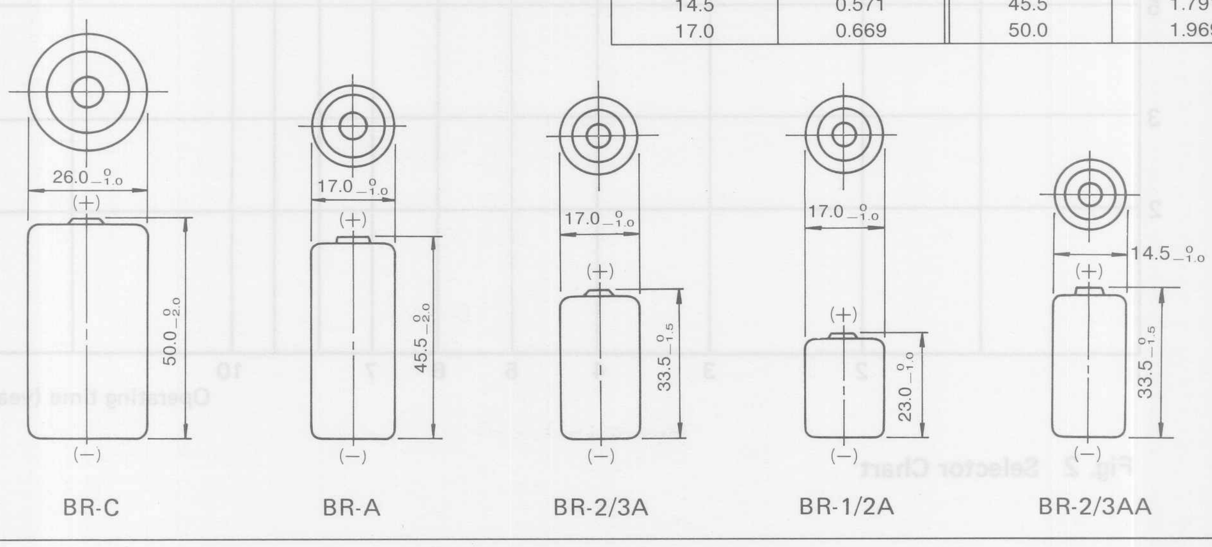
4.1 Specification

Model No.		BR-C	BR-A	BR-2/3A	BR-1/2A	BR-2/3AA
Nominal Voltage (V)		3	3	3	3	3
Nominal Capacity※(mAh)		5,000	1,800	1,200	650	600
Standard Drain (mA)		150	2,5	2,5	2	2
Continuous Maximum Drain (mA)		300	250	250	120	80
Pulse (mA)		max. 1,000	max. 1,000	max. 1,000	max. 500	max. 500
Dimension (Max.)	Diameter (mm)	26.0	17.0	17.0	17.0	14.5
	Height (mm)	50.0	45.5	33.5	23.0	33.5
Approx. Weight (g)		47.0	18.0	13.5	9.5	9.5
Temp. Range for Use(℃)		−40~+85 (−40~+185°F)				

※ Nominal Capacity shown above is based on standard drain down to 1.8V.
For low (microamper) drains, capacity is significantly higher, see selector chart Fig 2.

4.2 Dimensions (mm)

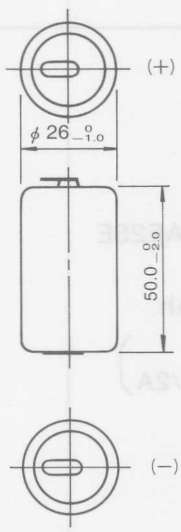
mm	inch	mm	inch
1.0	0.039	23.0	0.906
1.5	0.059	26.0	1.023
2.0	0.079	33.5	1.319
14.5	0.571	45.5	1.791
17.0	0.669	50.0	1.969



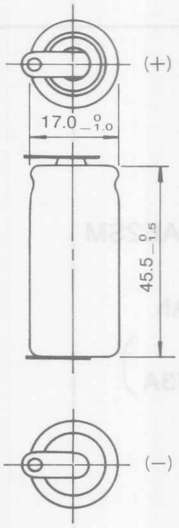
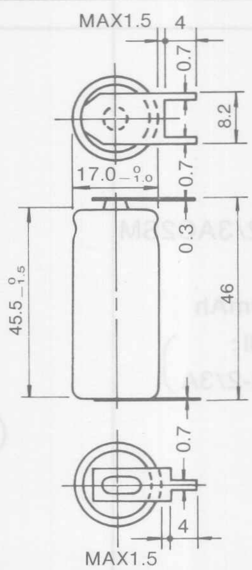
BR-C BR-A BR-2/3A BR-1/2A BR-2/3AA

4.3 Dimensions with Tab, Tab-pin or Connector

BR-C

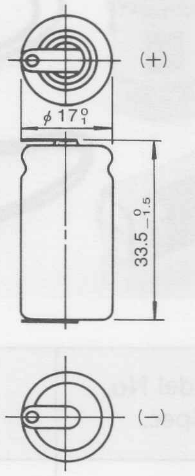
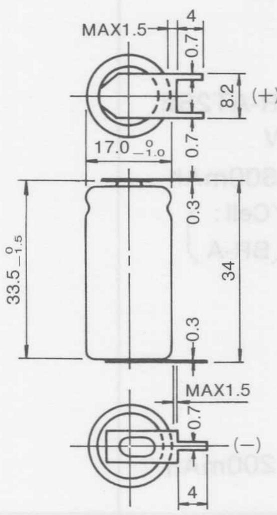
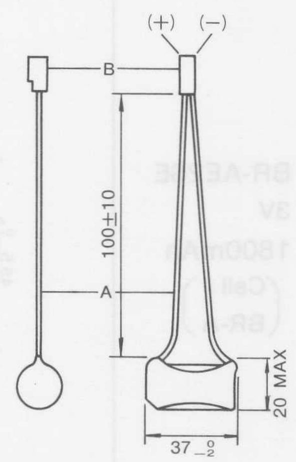
Model No. Spec.	Dimension (mm)
BR-CT2E 3V 5000mAh (Cell : BR-C)	

BR-A

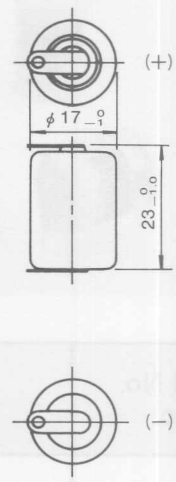
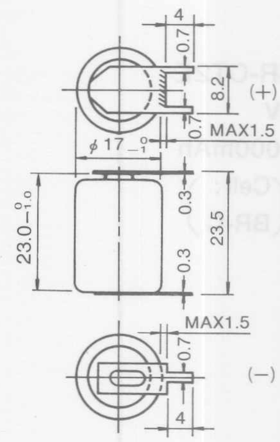
Model No. Spec.	Dimension (mm)
BR-AT2SE 3V 1800mAh (Cell : BR-A) 1200mAh	
BR-AE2SE 3V 1800mAh (Cell : BR-A)	

mm	inch	mm	inch
0.3	0.012	8.2	0.323
0.7	0.028	17.0	0.669
1.0	0.039	26.0	1.023
1.5	0.057	45.5	1.791
2.0	0.079	46.0	1.811
4.0	0.157	50.0	1.969

BR-2/3A

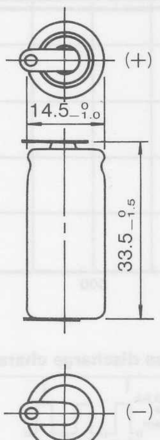
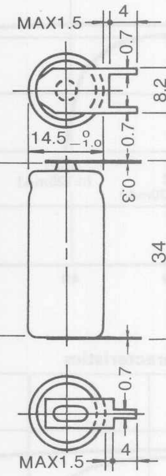
Model No. Spec.	Dimension (mm)
BR-2/3AT2SM 3V 1200mAh (Cell : BR-2/3A)	
BR-2/3AE2SM 3V 1200mAh (Cell : BR-2/3A)	
BR-2/3AC2SM 3V 1200mAh (Cell : BR-2/3A)	 A : Vinyl lead wire B : Connector

BR-1/2A

Model No. Spec.	Dimension (mm)
BR-1/2AT2SE 3V 650mAh (Cell : BR-1/2A)	
BR1/2AE2SE 3V 650mAh (Cell : BR-1/2A)	

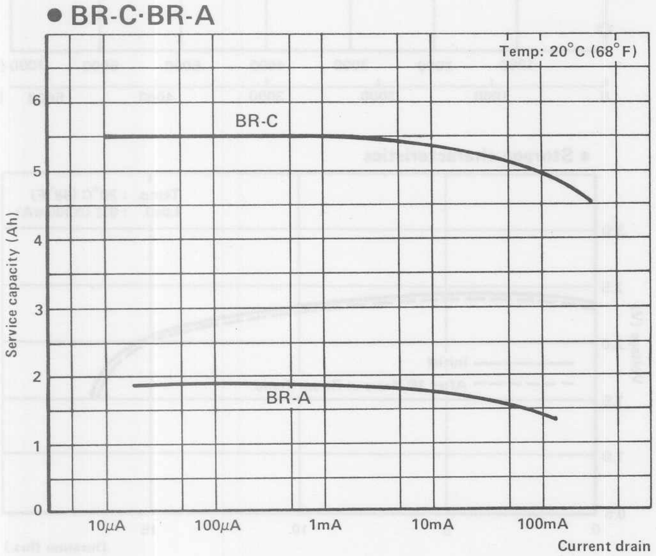
mm	inch	mm	inch
0.3	0.012	20.0	0.787
0.7	0.028	23.0	0.906
1.0	0.039	23.5	0.925
1.5	0.057	33.5	1.319
2.0	0.079	34.0	1.339
4.0	0.157	37.0	1.457
8.2	0.323	100.0	3.937
17.0	0.669		

BR-2/3AA

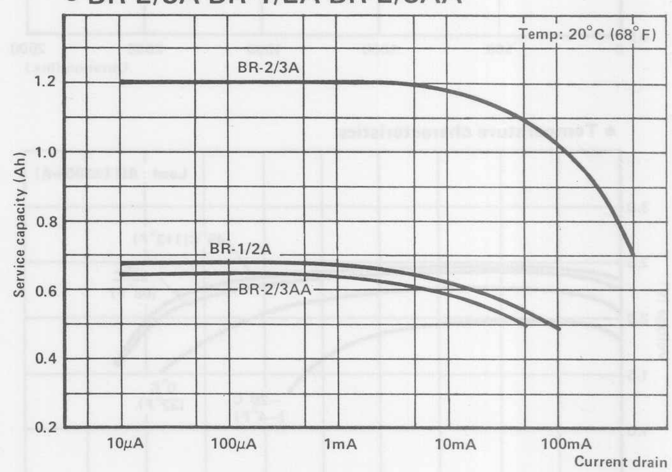
Model No. Spec.	Dimension (mm)	Model No. Spec.	Dimension (mm)
BR-2/3AAT2SE 3V 600mAh (Cell : BR-2/3AA)		BR-2/3AAE2SE 3V 600mAh (Cell : BR-2/3AA)	

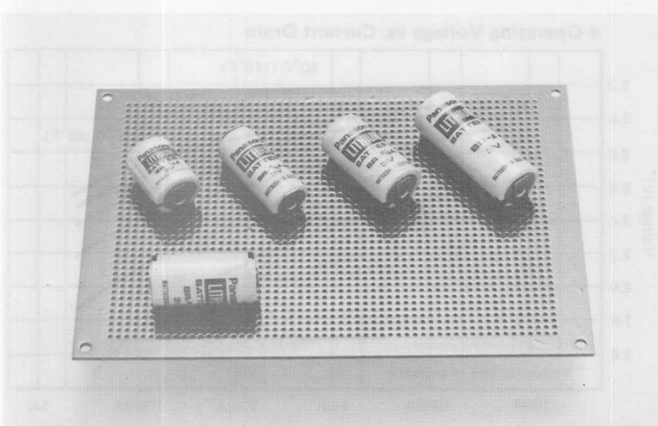
4.4 Service Capacity vs. Current Drain

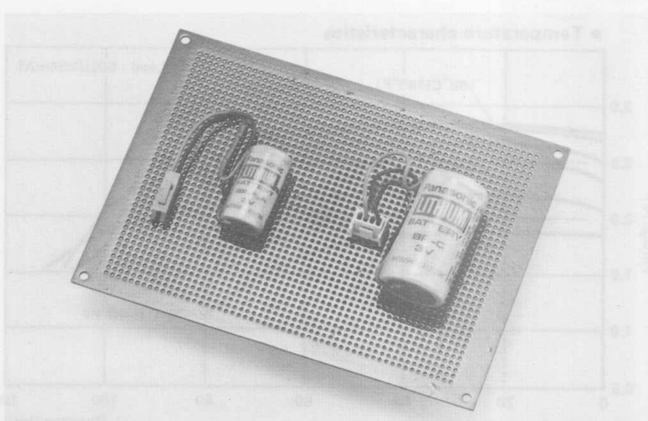
● BR-C·BR-A



● BR-2/3A·BR-1/2A·BR-2/3AA



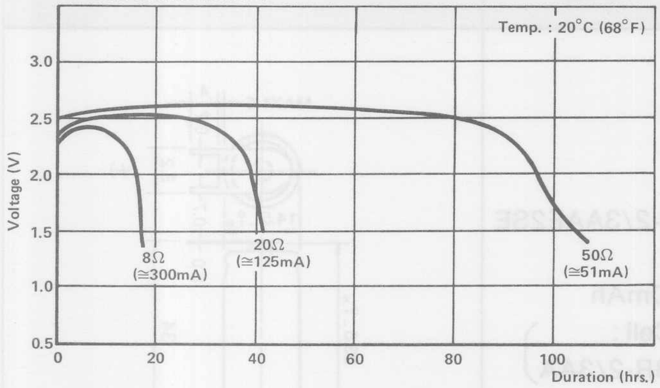




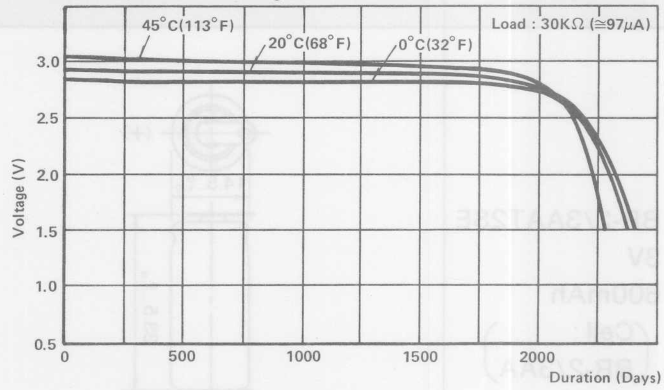
4.5 Individual Data Sheets

BR-C

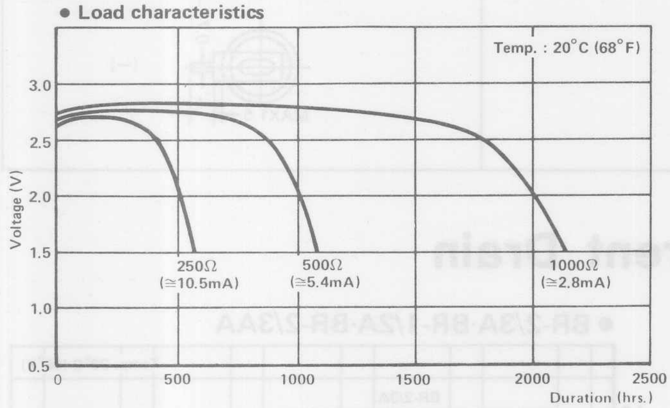
• **Load characteristics**



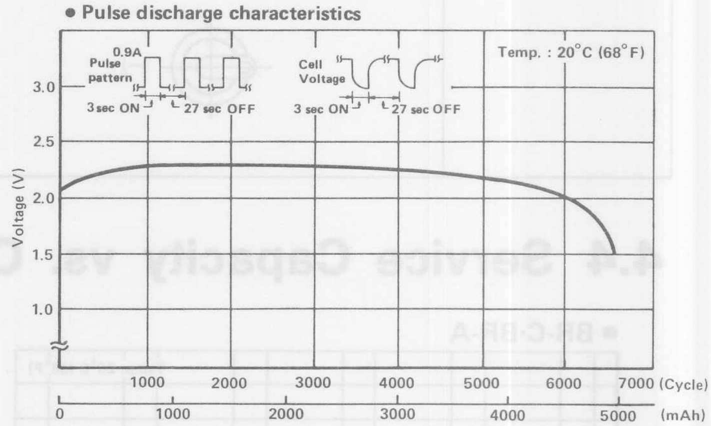
• **Long period discharge characteristics**



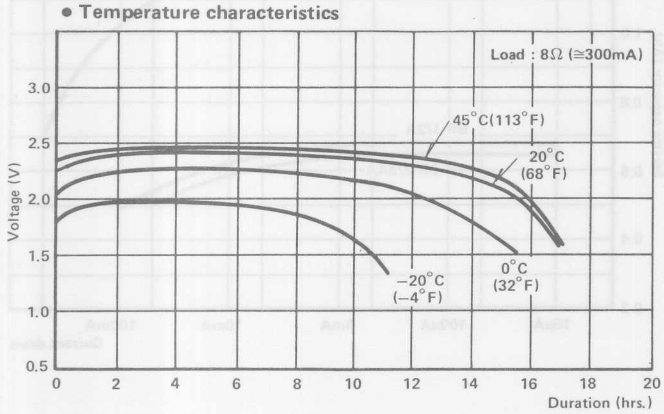
• **Load characteristics**



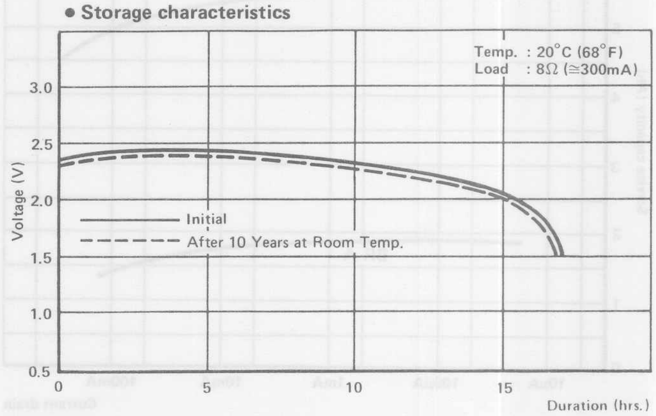
• **Pulse discharge characteristics**



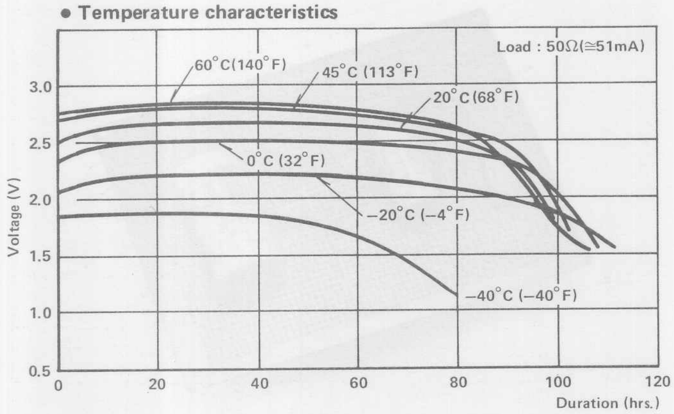
• **Temperature characteristics**



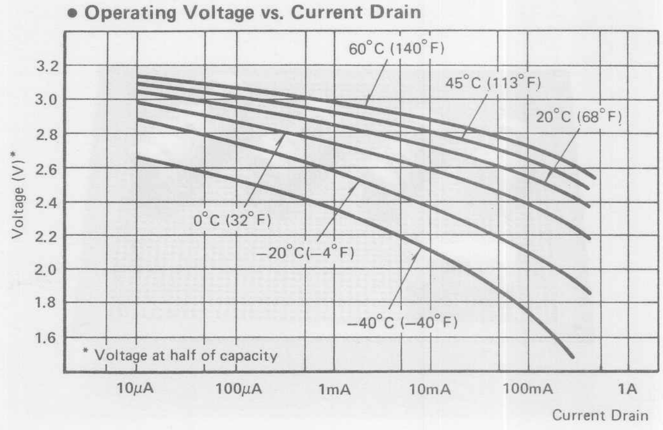
• **Storage characteristics**



• **Temperature characteristics**

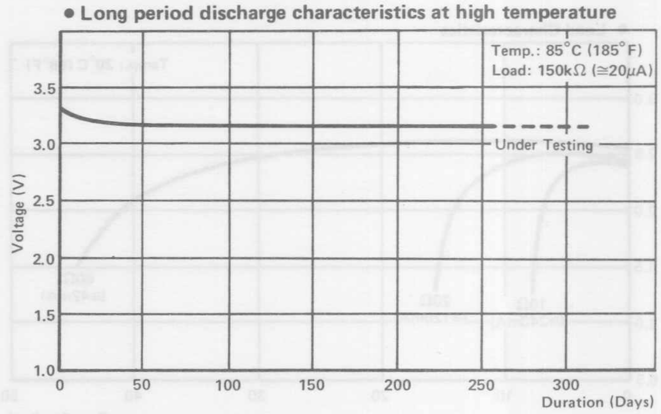


• **Operating Voltage vs. Current Drain**



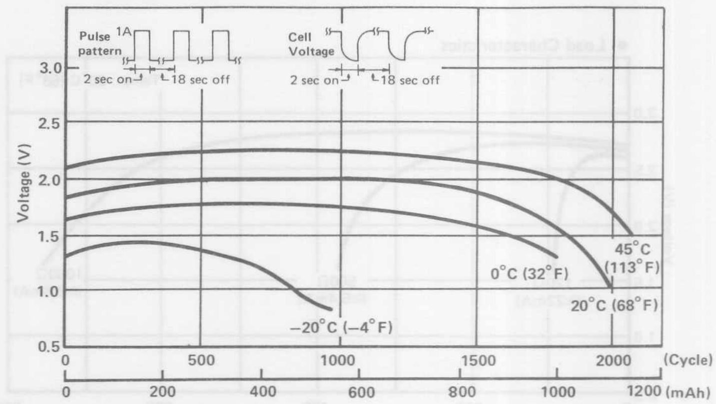
• Load characteristics

• Long period discharge characteristics at high temperature

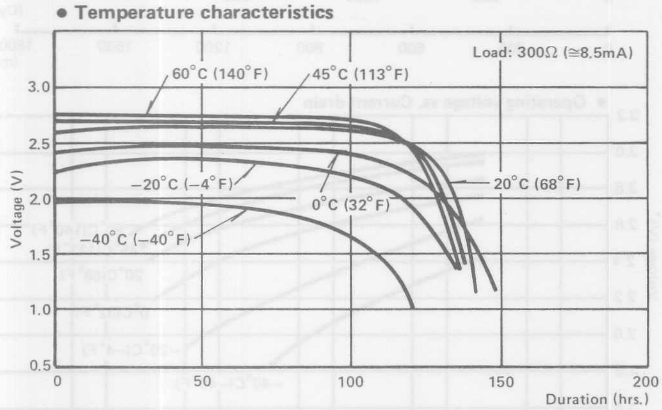


• Load characteristics

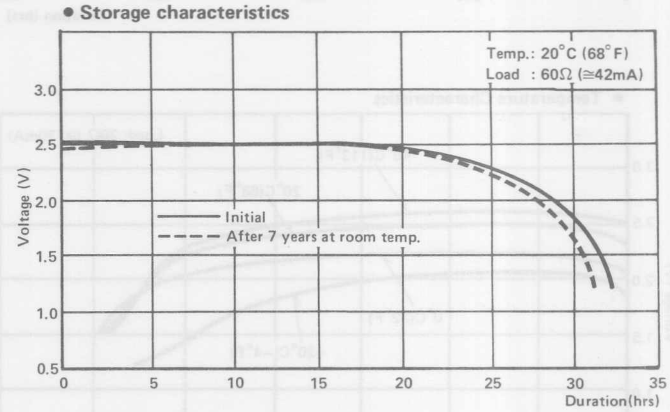
• Pulse discharge characteristics



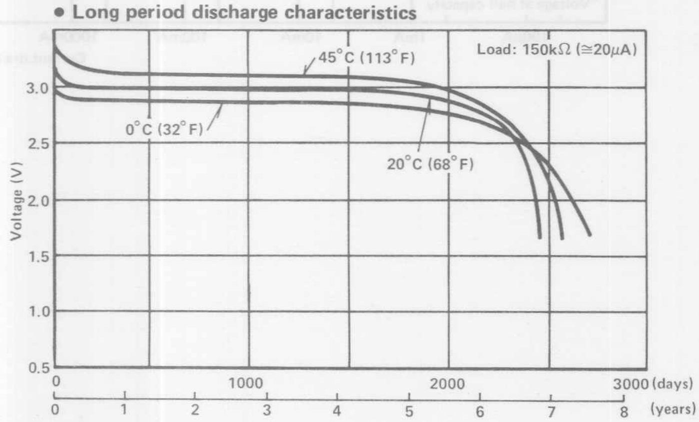
• Temperature characteristics



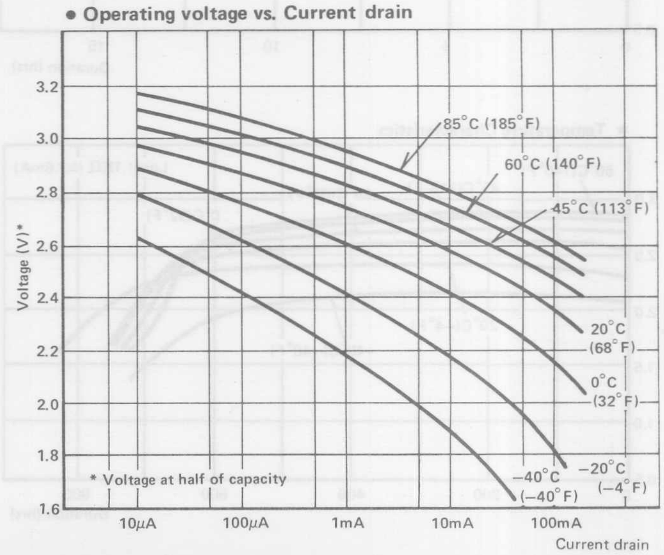
• Storage characteristics



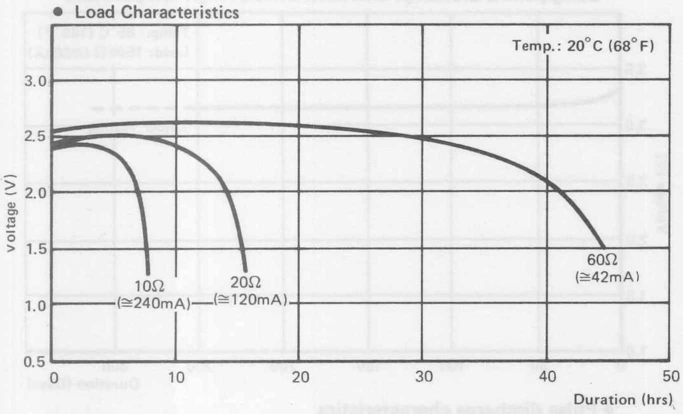
• Long period discharge characteristics



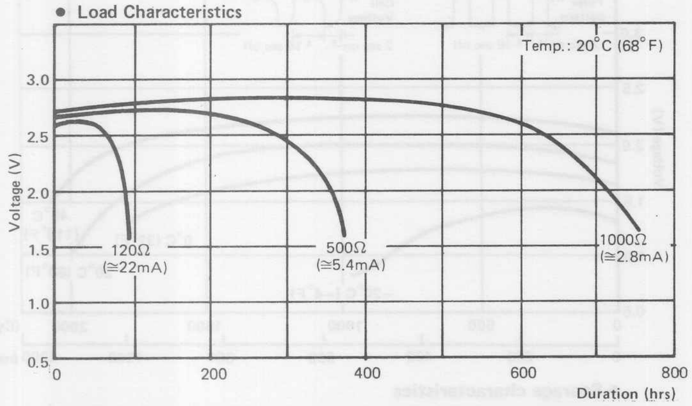
• Operating voltage vs. Current drain



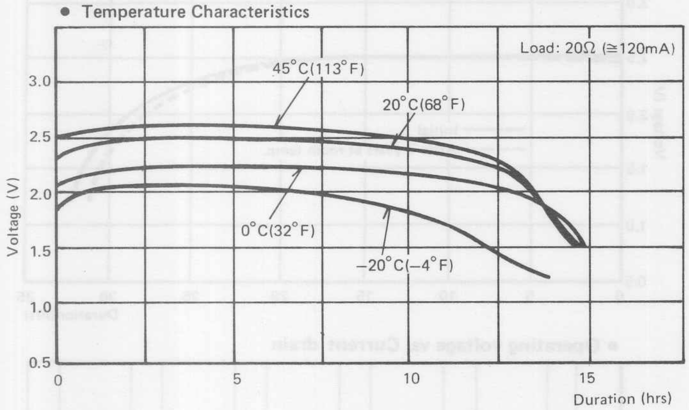
• Load Characteristics



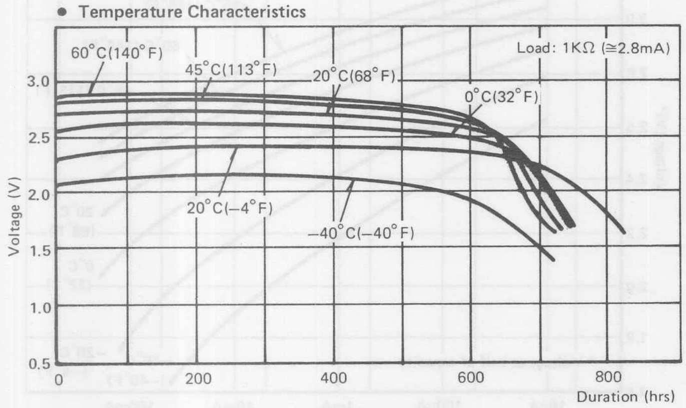
• Load Characteristics



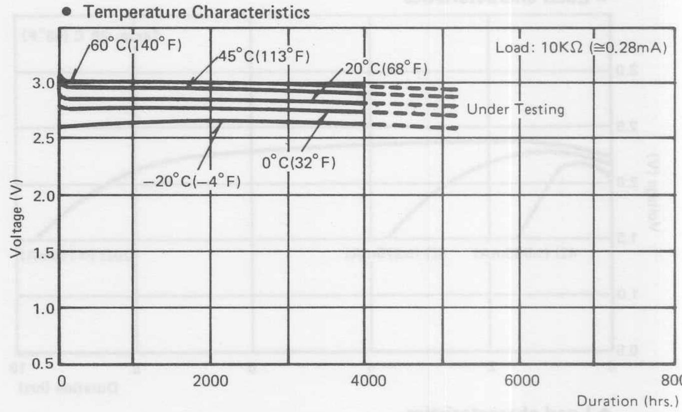
• Temperature Characteristics



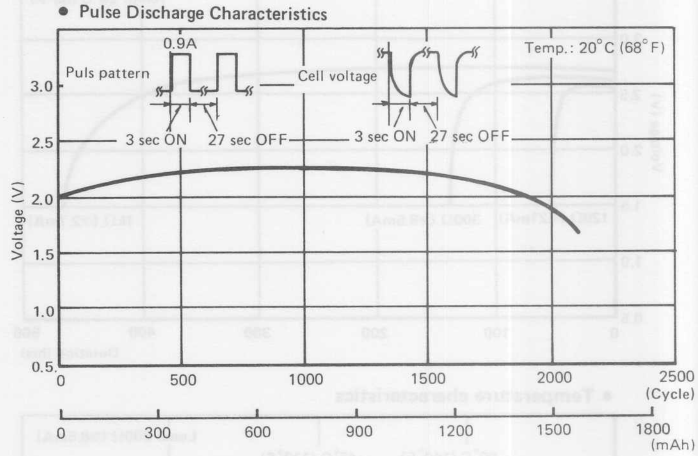
• Temperature Characteristics



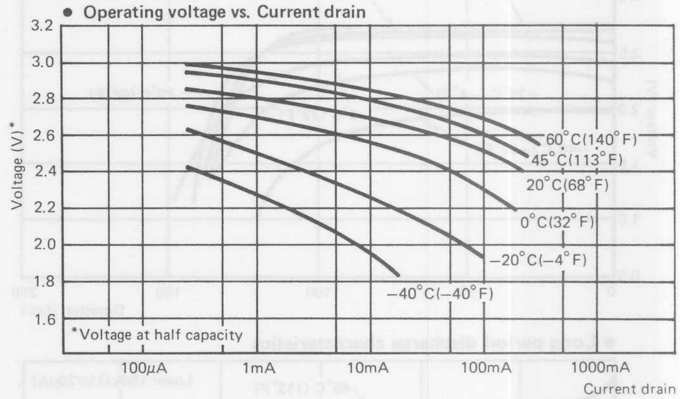
• Temperature Characteristics



• Pulse Discharge Characteristics

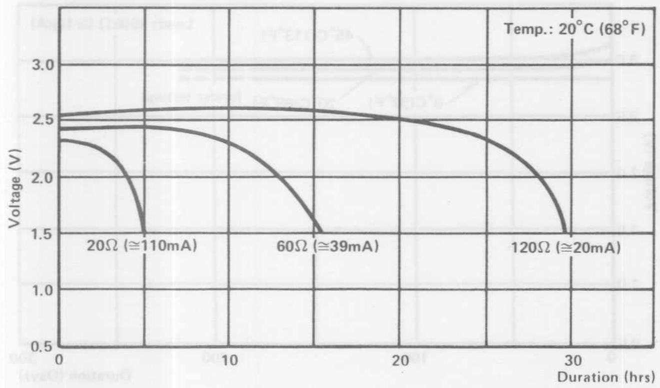


• Operating voltage vs. Current drain

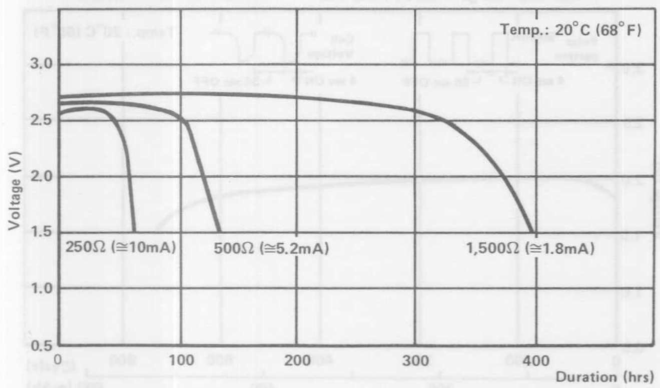


BR-1/2A

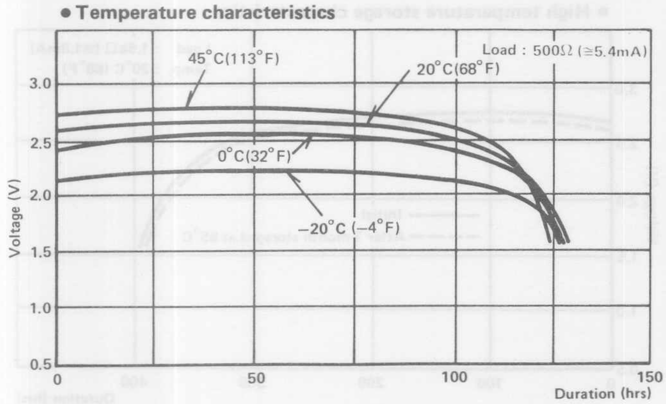
● Load characteristics



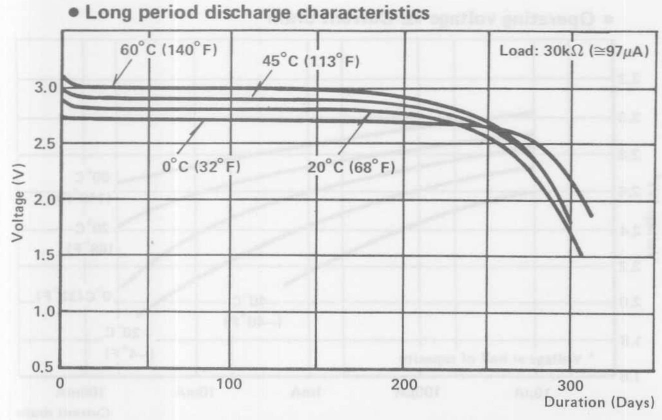
● Load characteristics



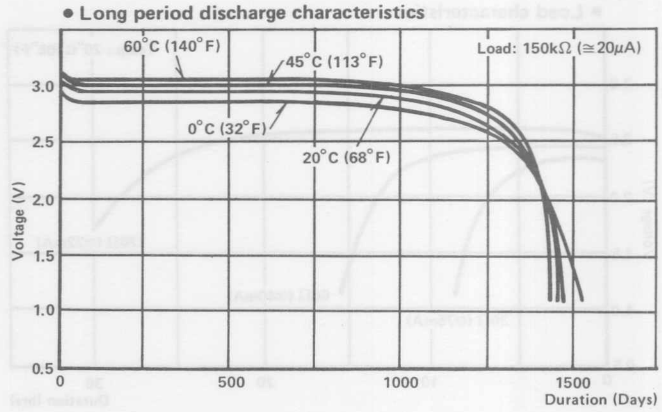
● Temperature characteristics



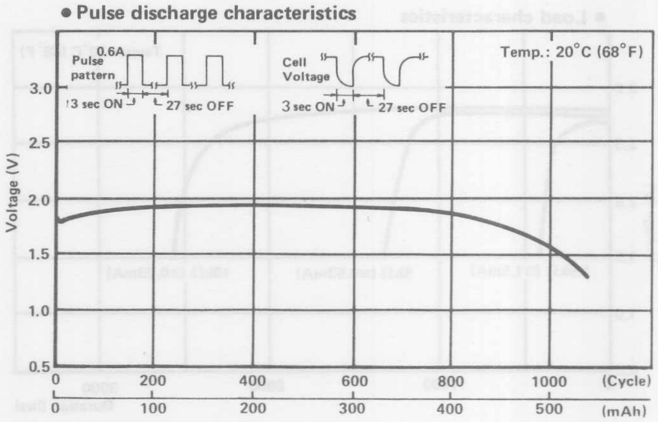
● Long period discharge characteristics



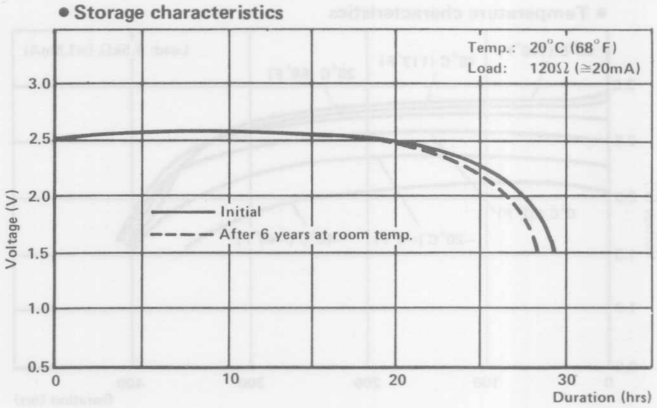
● Long period discharge characteristics



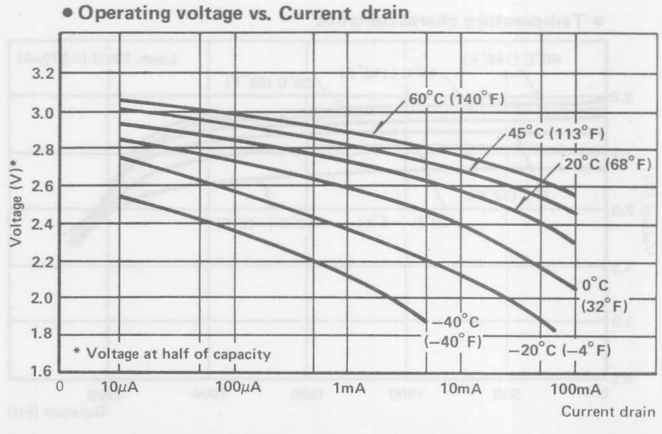
● Pulse discharge characteristics



● Storage characteristics

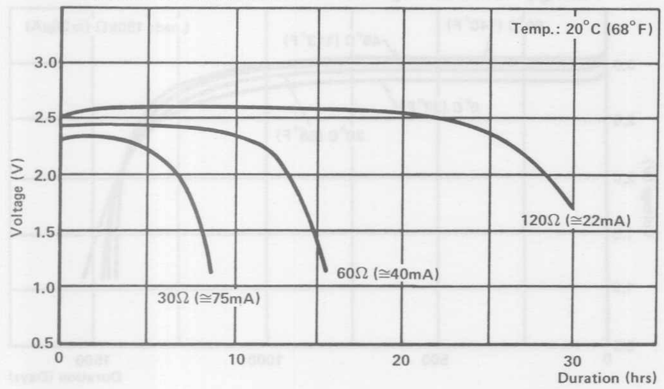


● Operating voltage vs. Current drain

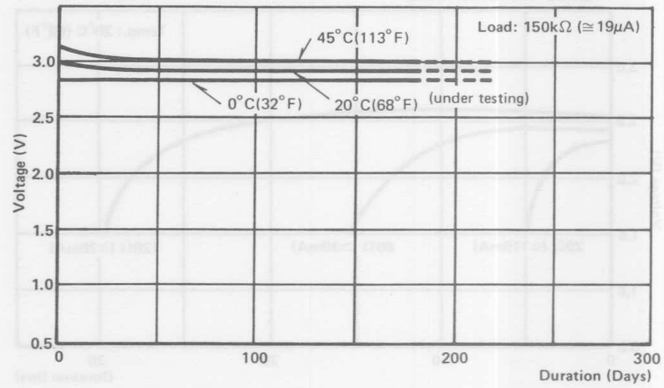


BR-2/3AA

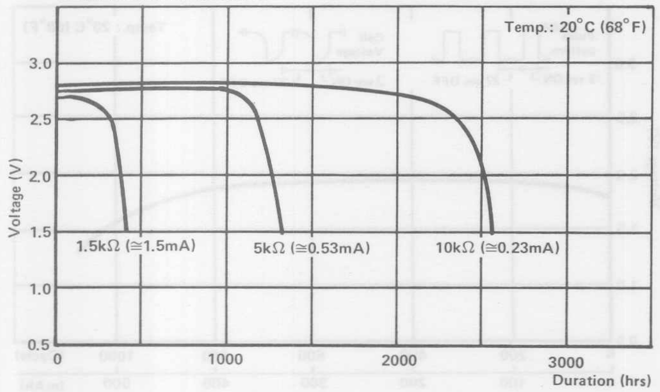
• **Load characteristics**



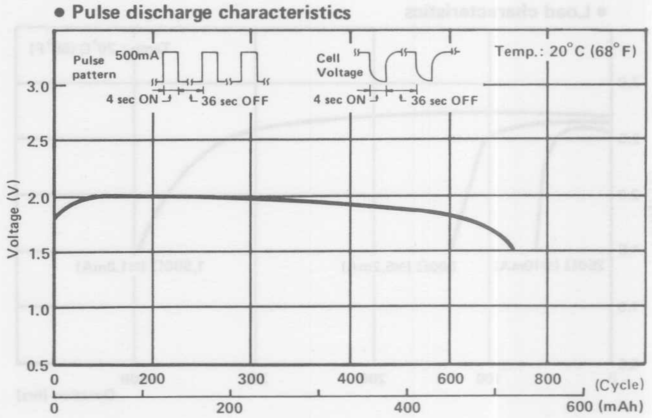
• **Long period discharge characteristics**



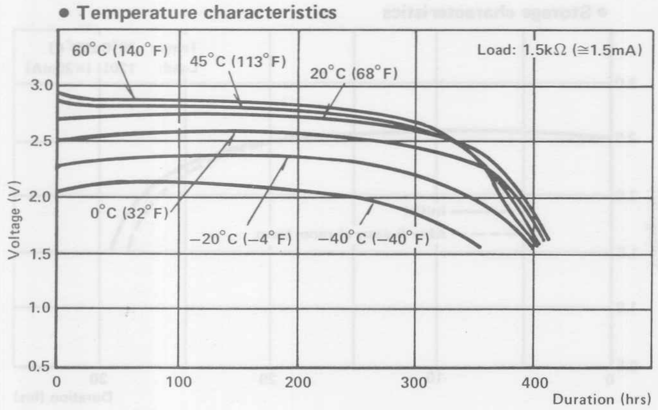
• **Load characteristics**



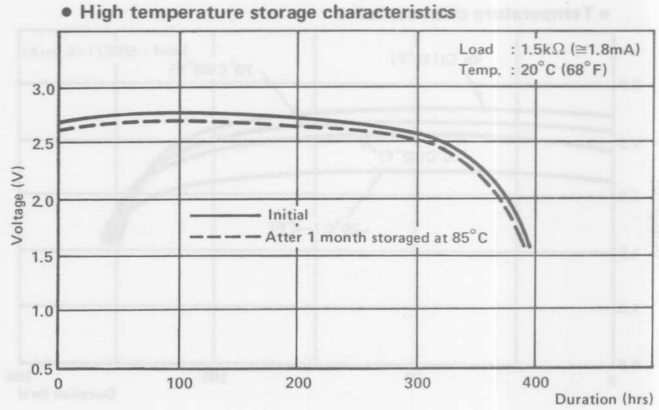
• **Pulse discharge characteristics**



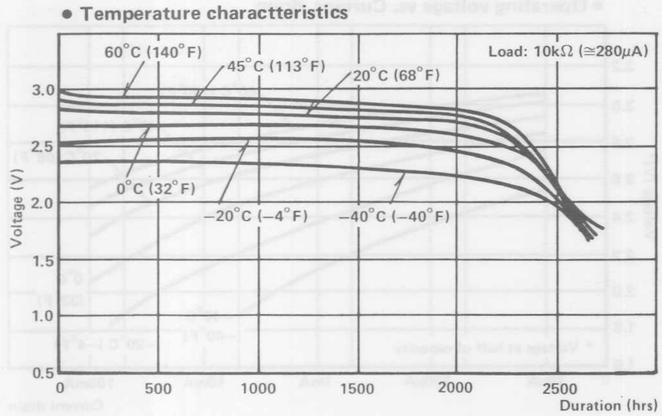
• **Temperature characteristics**



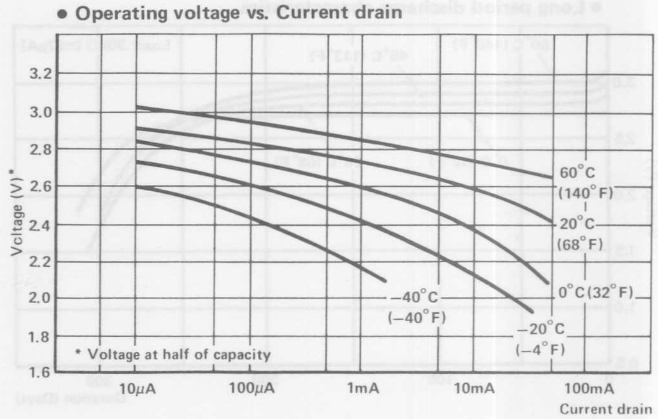
• **High temperature storage characteristics**



• **Temperature characteristics**



• **Operating voltage vs. Current drain**



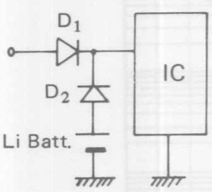
5. Memory Back-up Applications

5.1 General Description

Due to the rapid advances in semiconductor technology, the functions and performance of electronic equipment have greatly improved. It is now common for equipment to also have some form of memory function. If the main power source, which normally maintains the memory, is for some reason cut off, a back-up power source is required. Until now, primary batteries such as carbon zinc batteries and mercury batteries, or secondary batteries such as sealed nickel cadmium batteries have been used for this purpose. However, battery replacements of primary batteries after 1 or 2 years have been necessary due to their short shelf life (compared to lithium). (CF)n/Li batteries have long term reliability for up to 10 years or more as primary batteries and compare favorably with the life of the equipment itself. (CF)n/Li batteries can be handled like any other electronic component, and as a back-up battery has important advantages such as providing simplified and maintenance-free circuit designs.

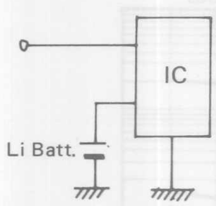
5.2 Back-up Circuit Applications

5.2.1 General



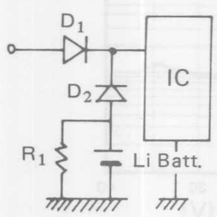
The IC in this circuit is usually operated by the main power source. During this time, there can be small current leaks through diode D2 to charge the lithium battery. When the main power source is cut off, the lithium battery supplies current to the IC. During the time, there is a forward voltage drop across diode D2. A small current leaks through diode D1 and dissipates the capacity of batteries.

5.2.2 Isolated Back-up



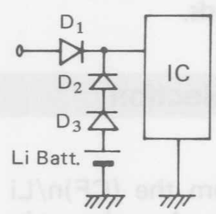
This memory circuit usually operates continuously by power from the lithium battery instead of from a main power source.

5.2.3 Bleeder Resistor



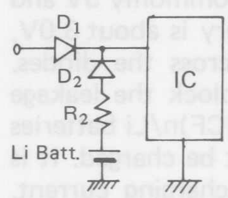
While the IC is being operated by the main power source, a current leaks through D2 and flows through resistor R1 to prevent the battery from being charged. The lithium battery always discharges through resistor R1 even while the IC is being operated by the main power source.

5.2.4 UL Standard (A) — Protective Diode



Diode D3 is added to the circuit in 5.2.1. Its purpose is to maintain protection in case one of the diodes becomes damaged. Note that while the lithium battery is supplying current to the IC when the main power source is cut off, the voltage drops due to the 2 diodes increases.

5.2.5 UL Standard (B) — Protective Resistor



Resistor R2 is inserted to reduce the charging current to the battery in the event the diode is damaged and shorts. Note that when only the battery supplies current (when the main power source is off), a voltage drop develops across R2.

5.3 IC Memory Back-up Design

5.3.1 Battery Selection

Battery Capacity:

The product of the current consumption of the IC memory and the total back-up time is the required electrical capacity. (If the back-up period is 10 years at 20μA, for 12 hours/day: 0.02mA x 12 hrs x 365 days x 10 years = 876mAh).

Battery Voltage:

The operating voltage depends on the current drain, ambient temperature, and battery size. Consider the voltage drop due to the protection diode and resistor when selecting a battery.
If an especially high voltage is required, 2 batteries can be connected in series.

Battery Size and Terminal:

There are several sizes of cylindrical and coin type batteries. Batteries are available with tabs, tab pins, pins, or various connectors. Select a battery according to the equipment space and shape. Consult with National for your special needs.

5.3.2 Protective Diode Selection

Diode D1:

This diode blocks the current from the (CF)n/Li battery to the main power source when the main power source is cut off. It is necessary that any leakage current does not affect the battery capacity.

Diodes D2 and D3:

Leakage Current:

Since the main power source is commonly 5V and the voltage of the (CF)n/Li battery is about 3.0V, a voltage of 2.0V is applied across the diodes. Diodes D2 and D3 must then block the leakage current resulting from the 2.0V. (CF)n/Li batteries are primary batteries and cannot be charged. It is thus necessary to suppress the charging current. The allowable charging current for the cylindrical type (CF)n/Li battery is specified to within 1% of the battery capacity.
Up to 12mAh is allowed for the total charging period for 1,200mAh BR-2/3A batteries.
If the total charging period is, say, 5 years, the allowed average leakage current becomes 12mAh ÷ 5 years ÷ 365 days ÷ 24 hrs = 0.27 μA (See 6.2.4).

Forward Voltage Drop:

The IC data retention voltage is commonly 2 ~ 2.5V. If the battery voltage is assumed to be 2.8V, a diode with a voltage drop of 0.3 ~ 0.8V is allowed. Although the power consumption is related to the IC, it is necessary to select a diode with a small voltage drop.
Although the leakage current is small, an example of a silicon diode (comparatively large forward voltage drop) is shown in Fig. 1 and an example of a Schottky diode (comparatively small forward voltage drop) is shown in Fig. 2. Examples of voltage variations when using these diodes in circuits are shown in Fig. 3 and Fig. 4.
It is necessary to select a diode with a low forward voltage drop when 2 diodes are to be connected in series.

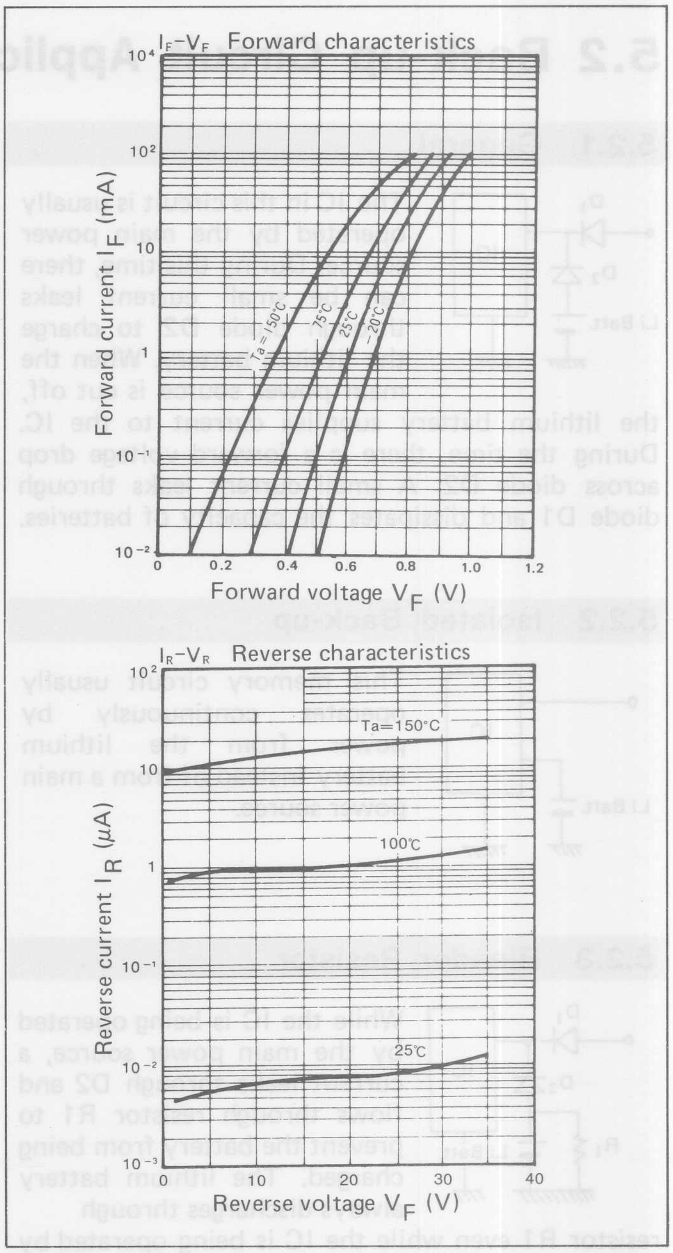


Fig. 1 Silicon diode characteristics

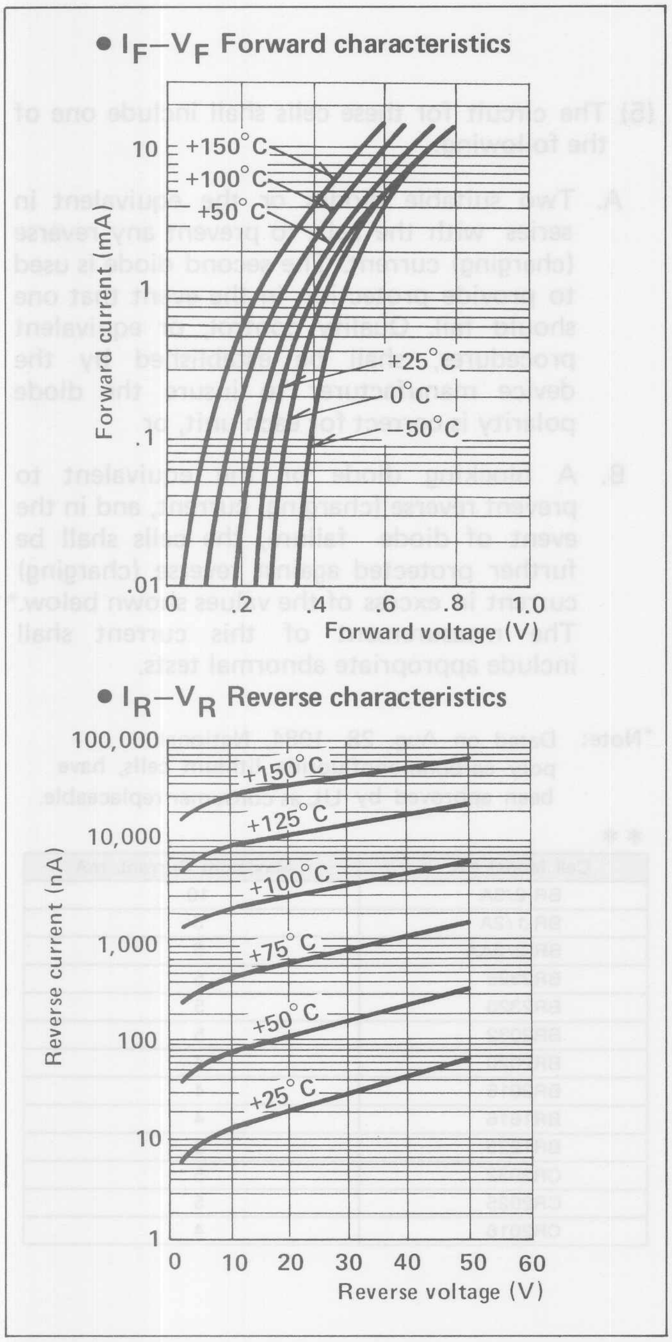


Fig. 2 Schottky diode characteristics

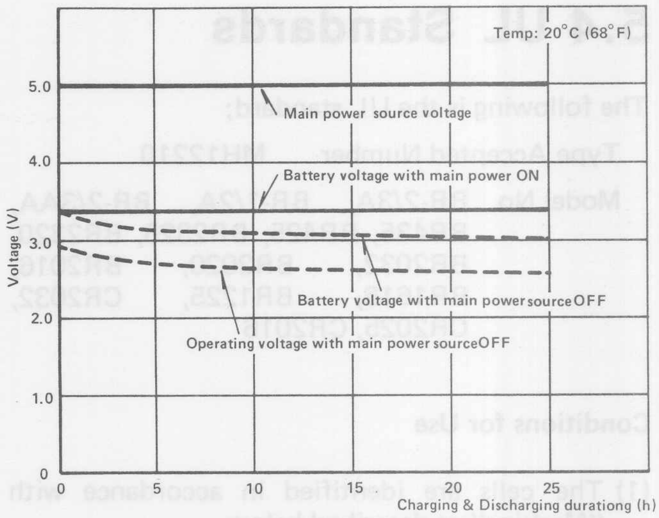


Fig. 3 Example 1: Use of silicon diode
Battery operation current: 10μA
Leakage current at charging: 6nA

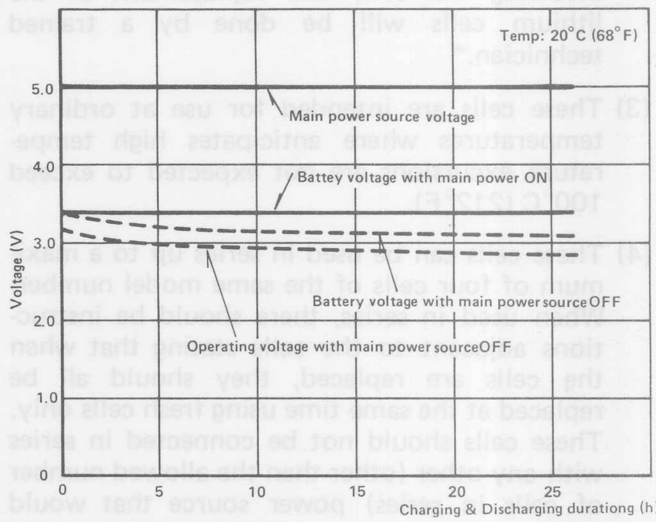


Fig. 4 Example 2: Use of schottky diode
Battery operating current: 10μA
Leakage current at charging: 4nA

5.3.3 Protective Resistor Selection

In the event that the diode is damaged, UL has determined (for safety) the maximum allowable charging current for each cell or battery. Resistor R2 is used to limit the current.
For details see section 7.3.2.
If the main power source is 5V and the battery voltage is 3V, then the voltage across resistor R2 is 2V. If the current is to be limited to 5mA, 2V ÷ 5mA = 400Ω, and a resistor of 400Ω or more should be connected.
If a 1,000Ω resistor is selected for safety, the voltage drop becomes 20μA* x 1,000Ω = 0.02V (*The maximum current consumption for IC is usually 20μA.)

5.4 UL Standards

The following is the UL standard;

Type Accepted Number MH12210

Model No. BR-2/3A, BR-1/2A, BR-2/3AA, BR435, BR425, BR2325, BR2320, BR2032, BR2020, BR2016, BR1616, BR1225, CR2032, CR2025, CR2016

Conditions for Use

(1) The cells are identified in accordance with "Marking" as described below.

(2) These cells are intended for use as components in devices where servicing of the circuitry involving the cells and replacement of the lithium cells will be done by a trained technician.*

(3) These cells are intended for use at ordinary temperatures where anticipates high temperature excursions are not expected to exceed 100°C (212°F).

(4) These cells can be used in series up to a maximum of four cells of the same model number. When used in series, there should be instructions adjacent to the cells stating that when the cells are replaced, they should all be replaced at the same time using fresh cells only. These cells should not be connected in series with any other (other than the allowed number of cells in series) power source that would increase the forward current through the cells.

(5) The circuit for these cells shall include one of the following:

A. Two suitable diodes or the equivalent in series with the cells to prevent any reverse (charging) current. The second diode is used to provide protection in the event that one should fail. Quality control, or equivalent procedures, shall be established by the device manufacturer to insure the diode polarity is correct for each unit, or

B. A blocking diode or the equivalent to prevent reverse (charging) current, and in the event of diode failure, the cells shall be further protected against reverse (charging) current in excess of the values shown below.** The measurement of this current shall include appropriate abnormal tests.

*Note: Dated on Aug. 28. 1984, National poly-carbonmonofluoride lithium cells, have been approved by UL as consumer replaceable.

**

Cell Model No.	Maximum Current, mA
BR-2/3A	10
BR-1/2A	5
BR-2/3AA	5
BR2325	5
BR2320	5
BR2032	5
BR2020	4
BR2016	4
BR1616	4
BR1225	3
CR2032	5
CR2025	5
CR2016	4

6. Safety Tests & Reference Data

6.1 Mechanical

6.1.1 Mechanical Vibration Test

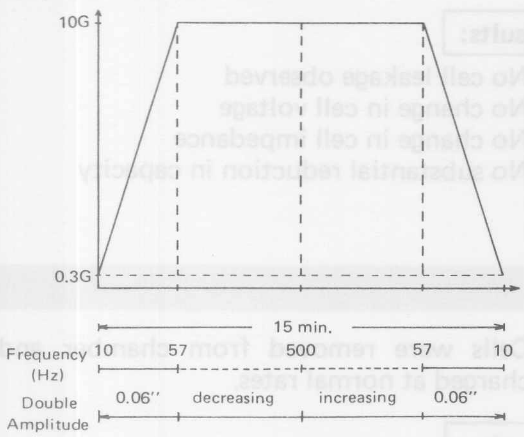
Test battery : BR-C, BR-2/3A
Test conditions : Conformed to Method 204C, MIL-STD-202E.

(1) **Vibration:**
Cells were subjected to simple harmonic motion of 0.06" double amplitude from 10 to 56Hz/sec., and 10G peak from 57 to 500Hz/sec.

(2) **Frequency:**
The vibration frequency were varied logarithmically between the 10 to 500Hz/sec. limit.

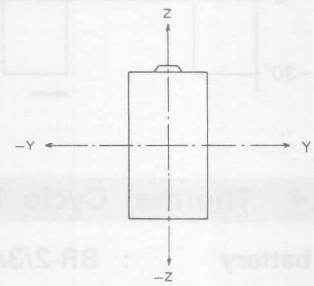
(3) **Test duration:**
The entire frequency range of 10 to 500Hz/sec. and return to 10Hz/sec. were transversed in 15 minutes.

The test pattern was as follows:



Test methods:

(1) The cells were secured to the vibration machine in the appropriate fixing jig.
(2) Vibration tests were performed in the two axes, as shown:



(3) The test was repeated twelve times for each axis.
(4) At conclusion of the vibration cycles the cells were discharged and various other observations made.

Results:

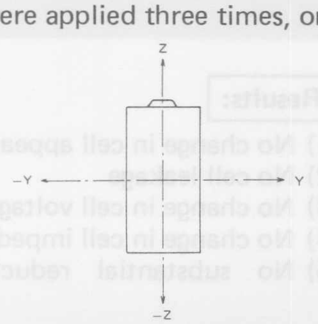
(1) No change in cell appearance
(2) No leakage observed
(3) No change in cell voltage
(4) No change in cell impedance
(5) No substantial reduction in capacity

6.1.2 Mechanical Shock Test

Test battery : BR-C, BR-2/3A,
Test condition : A half-sine pulse, of 200G peak acceleration for 5.5ms.

Test method:

(1) The cell was held firmly in a massive frame.
(2) Mechanical shocks were applied three times, on two axes, as shown:



(3) At conclusion of the shock test the cells were discharged and various other observations made.

Results:

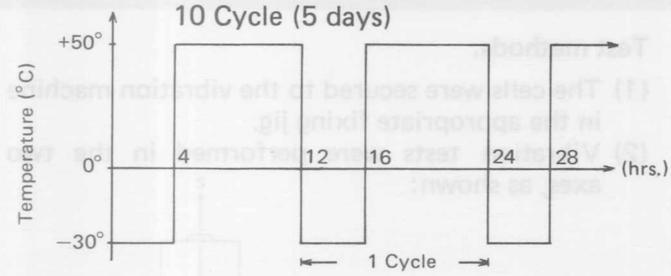
(1) No change in cell appearance
(2) No cell leakage
(3) No change in cell voltage
(4) No change in cell impedance
(5) No substantial reduction in capacity

6.1.3 Thermal Shock Test

Test battery : BR-C, BR-2/3A,

Test condition : Cells were subjected to 10 thermal cycles as follows:

1 Cycle: –30°C/4 hrs +50°C/8 hrs
10 Cycle (5 days)



Test method:

(1) The cells were subjected to temperature cycling as indicated.

(2) The cells were discharged at normal rates after stabilizing at 20°C and various observations made.

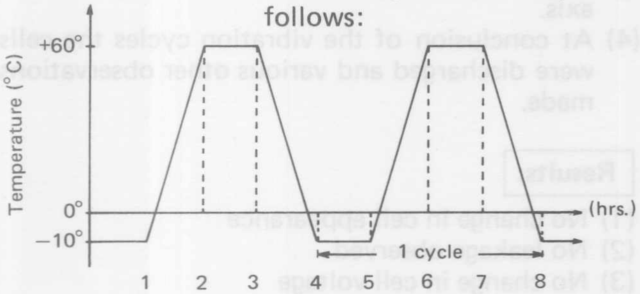
Results:

(1) No cell leakage observed
(2) No change in cell voltage
(3) No change in cell impedance
(4) No substantial reduction in capacity

6.1.4 Thermal Cycle Test

Test battery : BR-2/3A,

Test conditions : Cells were subjected to 120 thermal cycles (20 days) as follows:



Test method:

(1) The cells were subjected to temperature cycling as indicated.

(2) The cells were discharged at nominal rate after stabilizing at 20°C and various observations made.

Results:

(1) No cell leakage observed
(2) No change in cell voltage
(3) No change in cell impedance
(4) No substantial reduction in capacity

6.1.5 Reduced pressure Test (High Altitude)

Test battery : BR-2/3A

Test temperature : Room temperataure

Test method:

(1) Cells were weighed before and after test.

(2) Cells were placed in vacuum chamber and subjected to a pressure of 3mmHg (i.e. 122,000 ft) for 10 days.

(3) Cells were removed from chamber and discharged at normal rates.

Results:

(1) No change in cell appearance
(2) No leakage observed
(3) No change in cell voltage
(4) No change in cell impedance
(5) No substantial reduction in cell capacity

6.1.6 Drop Test

Test battery: BR-C, BR-2/3A

Test method:

(1) Cells were randomly dropped five times onto the concrete from 102cm (40") height.

(2) Cells were discharged at normal rates after drop.

Results:

(1) No change in cell appearance
(2) No cell leakage
(3) No change in cell voltage
(4) No change in cell impedance
(5) No substantial reduction in cell capacity

6.2 Electrical

6.2.1 Short Circuit Test

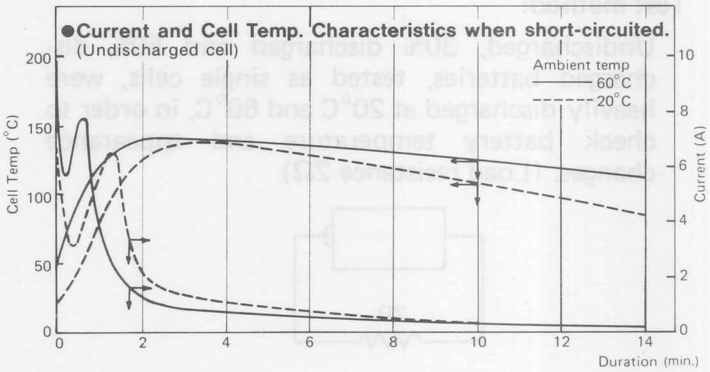
Test battery: BR-2/3A

Test method:

Undischarged, 30% discharged and 50% discharged batteries, tested as single cells, were short-circuited at 20°C and 60°C, in order to check battery temperature and appearance changes.

Result:

No rupture, ignition of explosion occurred when batteries above were individually short-circuited at 20°C and 60°C.

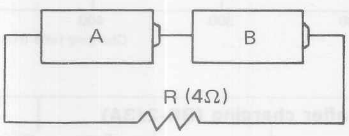


6.2.2 Forced Discharge Test

Test battery: BR-2/3A

Test method:

A 50% discharged battery was connected with undischarged battery according to the circuit diagram below and discharged at –20°C, 20°C and 60°C, in order to check voltage, temperature and appearance.

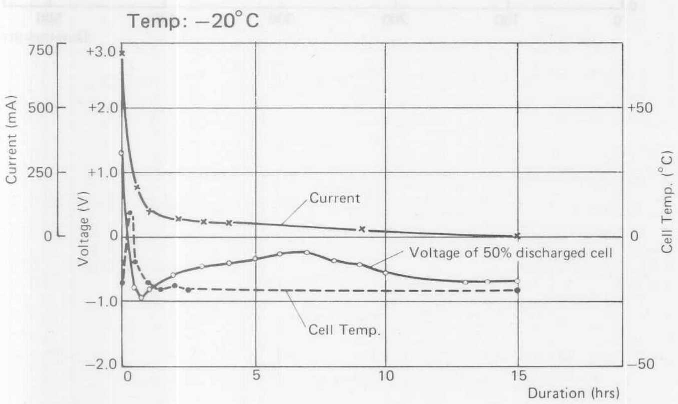


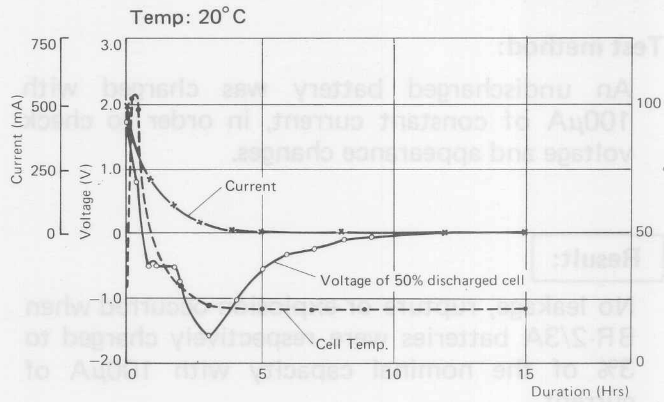
A: 50% discharged battery
B: Undischarged battery
R: Load resistance (4Ω)

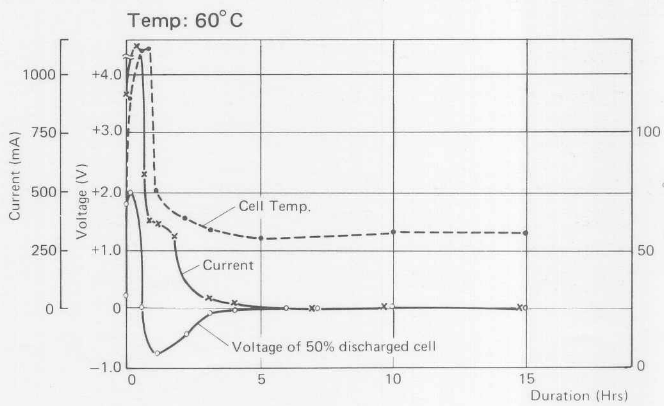
Results:

(1) No rupture
(2) No ignition
(3) No cell leakage

● **Current and Cell Temp. Characteristics**





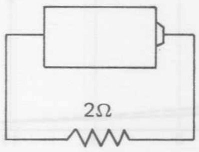


6.2.3 Heavy Duty Discharge Test

Test battery: BR-2/3A

Test method:

Undischarged, 30% discharged and 50% discharged batteries, tested as single cells, were heavily discharged at 20°C and 60°C, in order to check battery temperature and appearance changes. (Load resistance 2Ω)



Results:

(1) No change in cell appearance
(2) No cell leakage
(3) Values in the following table show maximum temperature reached (after about 30 minutes).

Test Battery	Test Temperature	
	20℃	60℃
Undischarged battery	79℃	138℃
30% discharged battery	83℃	105℃
50% discharged battery	81℃	91℃

6.2.4 Charge Test

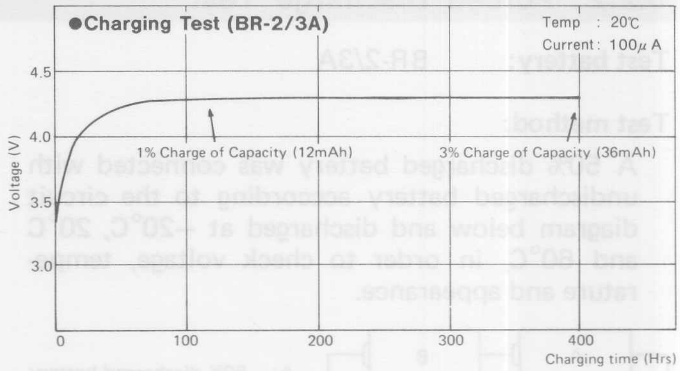
Test battery: BR-2/3A

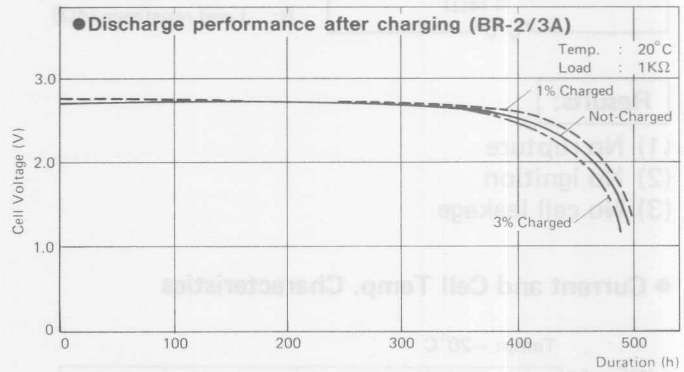
Test method:

An undischarged battery was charged with 100μA of constant current, in order to check voltage and appearance changes.

Result:

No leakage, rupture or explosion occurred when BR-2/3A batteries were respectively charged to 3% of the nominal capacity with 100μA of current.





6.3 Special

6.3.1 High Temperature Storage Test

Test battery: BR-2/3A

Test method:

Undischarged and 50% discharged batteries were stored for a given time at 70°C and 120°C, in order to check voltage and appearance changes.

Test Item		Voltage	Appearance
Battery	Test Condition		
Undischarged battery	70℃×72h	No change	No change
	120℃×16h	No change	PVC jacket damaged
50% discharged battery	70℃×72h	No change	No change
	120℃×16h	No change	PVC jacket damaged

Results:

(1) No cell leakage
(2) No rupture or ignition

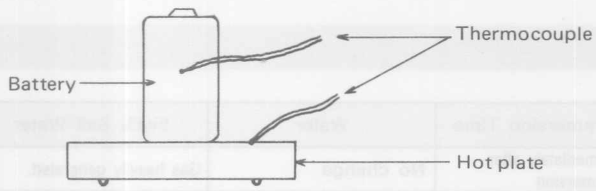
6.3.2 Hot Plate Test

Test battery: BR-2/3A

Test method:

Undischarged and 50% discharged batteries were placed on a hot plate and heated as seen in below in order to check voltage changes and battery temperature.

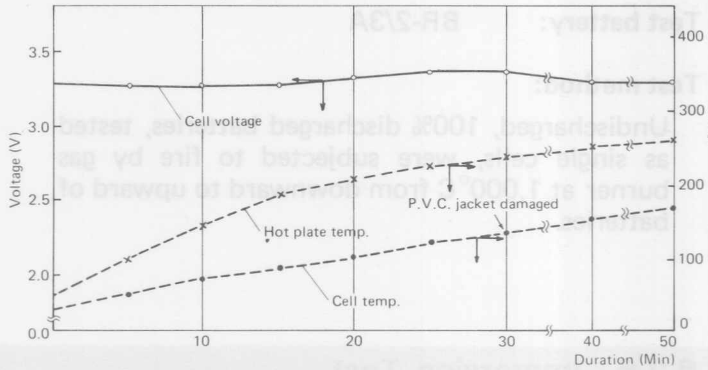
The battery temperature was measured at the thermocouple connected with the battery surface.



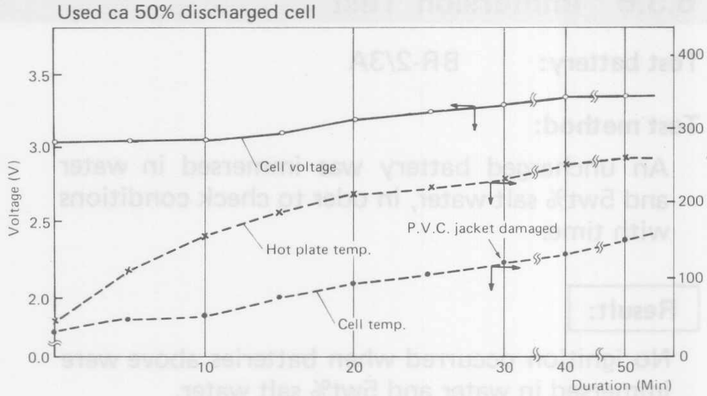
Result:

No rupture, ignition or explosion occurred when batteries above were heated up to 180°C on a hot plate.

Used Non discharged cell



Used ca 50% discharged cell



6.3.3 Drilling Test

Test battery: BR-2/3A

Test method:

Undischarged and 50% discharged batteries were gripped with a vise and drilled diametrally with an electric drill, in order to check voltage, temperature and appearance changes. (Drill dia: ϕ4mm)

Drill Test Item		Voltage Change	Battery Temperature Max.	Appearance
Battery	Drill Speed			
Undischarged battery	2,800 rpm	3.30V ↓ 0.15V	112℃	PVC jacket damaged. White smoke produced.
	500 rpm	3.30V ↓ 0.40V	144℃	PVC jacket damaged. Top swelled. White smoke produced.
50% discharged battery	2,800 rpm	3.30V ↓ 0.35V	66℃	White smoke produced.
	500 rpm	3.30V ↓ 0.15V	103℃	White smoke produced.

Result:

Although the battery temperature rose due to short-circuit, no rupture, ignition or explosion occurred when batteries above were drilled.

6.3.4 Crush Test

Test battery: BR-2/3A

Test method:

Undischarged and 50% discharged batteries were crushed to half size diametrally with a hammer.

Crush Test Item		Voltage Change	Battery Temperature	Appearance
Battery	Test Condition			
Undischarged battery	hammer	3.24V ↓ 0.17V	Reached 149℃	Top deformed. Electrolyte leaked.
50% discharged battery	hammer	3.17V ↓ 0V	Reached 175℃	Top deformed. Electrolyte leaked.

Result:

Although the battery temperature rose due to short-circuit, no explosion occurred when batteries above were crushed to half size diametrally with a hammer.

6.3.5 Burning Test

Test battery: BR-2/3A

Test method:

Undischarged, 100% discharged batteries, tested as single cells, were subjected to fire by gas burner at 1,000°C from downward to upward of batteries.

Result:

All tested batteries were vent out and caught fire within 3 minutes, and **all of them had no explosion.**

6.3.6 Immersion Test

Test battery: BR-2/3A

Test method:

An uncharged battery was immersed in water and 5wt% salt water, in oder to check conditions with time.

Immersion Time	Water	5wt% Salt Water
Immediately after immersion	No change	Gas heavily generated.
40 min.	No change	Water turned brown.
2 hr.	Water turned brown.	Water turned brown.
18 hr.	Water turned brown.	+ terminal corroded & disassembled.
48 hr.	Water turned brown.	+ terminal dissolved.
96 hr.	+ terminal dissolved.	

Result:

No ignition occurred when batteries above were immersed in water and 5wt% salt water.

6.3.7 Salt Water Spray Test

Test battery: BR-2/3A

Test method:

Batteries were left for 8 hours after spraying with 5wt% salt water.

Result:

Although rust was produced in the sprayed sections, no leakage occurred.

Battery	Appearance
BR-2/3A	O.C.V. reduced approx. 50mV. Rust produced at cathode and anode terminals.

7. Care & Handling

Among the many types of lithium batteries, National (CF)n/Li batteries offer outstanding safety, however, since the contained lithium metal and flammable materials such as the organic electrolyte (boiling point is high——this is one of the most stable electrolytes), handle them carefully to prevent accidents.

7.1 General Precautions

- **Do not short the batteries.**
- **Do not charge the batteries.**
- **Do not connect the wrong polarity (+, −) of the batteries.**
- **Do not incinerate the batteries.**
- **Do not heat the batteries.**
- **Do not disassemble the batteries.**

7.2 Protective Devices

7.2.1 Fuses

- **When more than one battery is used in a circuit,** to prevent incorrect connection, the use of the preassembled battery is preferable to the use of individual batteries that are installed individually in a holder. To prevent short circuits, a fuse or resistor should be used in the assembled battery. (Custom battery assemblies are available from National or our authorized modification centers.)
- Where possible, a fuse should be also used in the equipment itself. If the battery assembly is used, select a fuse with a current capacity smaller than that of the battery. When the load current is small, use an appropriate resistor which is not affected by voltage drops.

7.2.2 Resistors & Diodes

- When used for memory back-up, insert a diode or resistor in the circuit so that the batteries do not receive leakage current from the main power source. This also prevents charging and excessive discharging. For details, see section 5.2 and 5.3 which describe the use of lithium batteries for memory back-up.

7.3 Soldering

7.3.1 Hand Soldering

Do not directly solder to the battery terminals. When it is necessary to connect a lead wire to the battery terminal, first spot-weld a tab to the terminal to prevent the battery from heating. Keep the soldering time as short as possible (5 to 10 seconds). Batteries with solder tabs are available as standard products from National.

7.3.2 Dip Soldering (See also 2.5.13.)

When a battery is mounted onto a PC board using tabs, and then dipped in a solder bath, the battery is temporarily short circuited. This is required for the voltage to recover even for slight shorts. Note that if its electrical characteristics are measured while the battery is recovering, the battery may appear to be defective. The recovery characteristics of the voltage after the slight short are shown in Fig. 1. The relationship between the short-time and the reduction in capacity is shown in Fig. 2. Keep the dipping time below 5 seconds. If the battery drops into the solder bath during dipping, rapid heating may cause an explosion. Extreme care must be taken to prevent dropping the battery. The cleaning solution used to clean the PC board after dipping into the solder bath may affect the battery. Please consult National for recommended cleaning solutions.

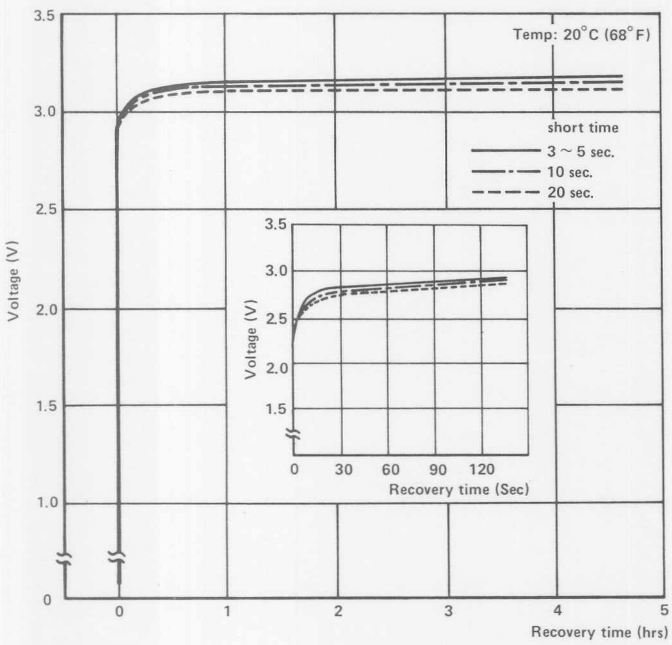


Fig. 1 BR-2/3A Voltage recovery characteristics after short test

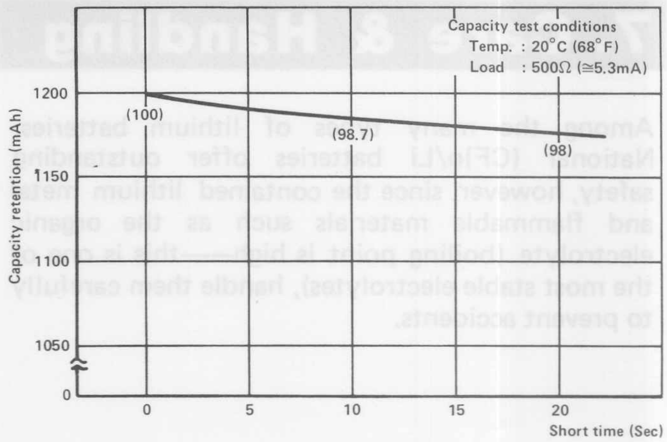


Fig. 2 BR-2/3A Capacity retention vs. Short time

7.4 Storage

- Storage Precautions
  Do not store batteries at extreme temperatures. (Keep the storage temperature within 0°C ~ 45°C.) Do not allow condensation to form on the batteries. Do not expose batteries to direct sunlight.